BBC

WHAT OUT-OF-BODY EXPERIENCES TELL US ABOUT THE BRAIN

SCIENCE AND TECHNOLOGY

FOCUS

VOYAGER SPECIAL

BEYOND OUR SOLAR SYSTEM

Can NASA's probe solve the secrets of the interstellar void?

THE A TO Z OF YOU

Inside the Human Cell Atlas project

FIND OUT

DO SUPERFOODS REALLY EXIST?

CAN BIRDS FLY UPSIDE DOWN?

WHAT IS THE WORLD'S SMALLEST ROBOT?

10 SCIENTIFIC WONDERS TO SEE BEFORE YOU DIE

UK PETROL & DIESEL BAN: WILL IT WORK?

#312 | £4.99 Sep 2017 sciencefocus.com

09 >

9 770966 427166

D3400

Nikon 100th anniversary

I AM WHAT I SHARE

I AM THE NEW NIKON D3400. Impress your friends and family with stunning Nikon image quality, thanks to my large 24.2 MP sensor and versatile NIKKOR lenses. I use Nikon's SnapBridge app to automatically transfer images via Bluetooth® to your compatible smart devices* as you take them. I make sharing your high quality images easier than ever. I am what I share. **nikon.co.uk**

The Bluetooth® word mark and logos are registered trademarks owned by Bluetooth SIG, Inc. Android® and Google Play® are trademarks of Google Inc.

*This camera's built-in Bluetooth® capability can only be used with compatible smart devices. The Nikon SnapBridge application must be installed on the device before it can be used with this camera. For compatibility and to download the SnapBridge application, please visit Google Play® and App Store.

Nikon

At the heart of the image

Eating a polar bear's liver would kill you → p84

WELCOME

It's easy to get sentimental about the Voyager mission. It's not a very scientific thing to say, but there's a whiff of destiny about it. The twin spacecraft, which would make their way to the outer planets before leaving our Solar System altogether, were essentially the invention of two interns: Michael Minovitch and Gary Flandro. In 1962 Minovitch figured out how to surf the gravitational pull of the planets to swing spacecraft across the Solar System, without a drop of propellant. Minovitch even plotted a theoretical trip that could carry a craft right to the outer planets. Unfortunately, most NASA scientists were preoccupied with Apollo missions at the time, so his ideas went unnoticed. Then a few years later, Flandro noticed that the planets were going to align into a trajectory Minovitch had plotted. A spacecraft would have to leave in the next decade if it was going to ride this planetary alignment to Neptune. And so the Voyager mission was born. Discover the whole story on p39.

Also, a note for our subscribers. From 22 August we will be moving our customer service operations. This will not affect your magazine subscription and you don't need to take any action. From this date your personal data, together with any other data relating to your subscription, will be held and processed by our trusted partner dsb.net Limited of 3 Queensbridge, The Lakes, Northampton, NN4 7BF.

How to contact us:

Email us at **bbcfocus@buysubscriptions.com** or visit **buysubscriptions.com/customer-services/FAQs**

Daniel Bennett, Editor

IN THIS ISSUE

KAT ARNEY

Geneticist Kat is a presenter on BBC Radio 5 podcast *The Naked Scientists*. This issue, she meets the researchers who are mapping every cell in the human body. → p65

SUSAN BLACKMORE

Susan is a psychologist who specialises in consciousness and anomalous experiences, making her the ideal expert to investigate out-of-body experiences. → p70

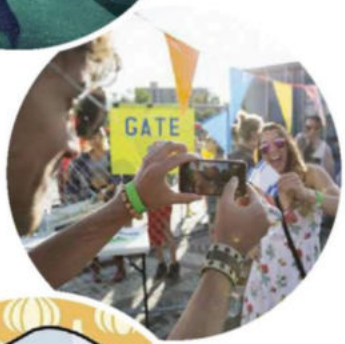
JAMIE CARTER

Need some cool science-y activities to add to your bucket list? Let eclipse chaser and photographer Jamie take you on a trip around the world. → p56

WHAT WE'VE FOUND OUT THIS MONTH

On 12 October a large asteroid could come within 6,800km of Earth → p11

Whales learn songs verse by verse, just like we do → p21



In the future gig tickets could become ultrasonic sounds to stop touts → p30

Stainless steel really does remove the smell of garlic from your hands → p86

CONTACT US

Advertising
neil.lloyd@immediate.co.uk
0117 300 8276

Letters for publication
reply@sciencefocus.com

Editorial enquiries
editorialenquiries@sciencefocus.com
0117 314 7388

Subscriptions
bbcfocus@buysubscriptions.com
03330 162 113*

Other contacts
sciencefocus.com/contact

WANT MORE? FOLLOW SCIENCEFOCUS

FACEBOOK
TWITTER
PINTEREST
GOOGLE+

COVER: MAGIC TORCH

*Calls from landlines will cost up to 9p per minute. Calls from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-6pm weekdays and 9am-1pm Saturday for orders only. If calling from overseas, please call +44 1604 973 721.

BBC Science Focus (ISSN 0966-4270)(USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a Christmas issue in December) by Immediate Media Company, Bristol, 2nd Floor, Tower House, Fairfax St., Bristol BS1 3BN. Distributed in the US by Circulation Specialists, LLC, 2 Corporate Drive, Suite 945, Shelton, CT 06484-6238. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

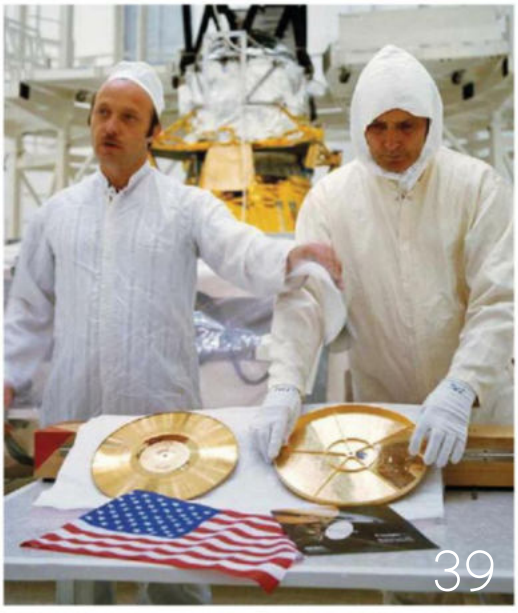
CONTENTS

25

REGULARS

48

FEATURES



MORE FOR YOU

Don't forget that *BBC Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. **sciencefocus.com**

Special issue

EARTH FROM ABOVE

The latest special edition from the *BBC Focus* team lets you explore the planet as never before, with fascinating photos taken from above the Earth's surface.

buysubscriptions.com/focuscollection

Only have eyes for you

EMILIA-ROMAGNA,
ITALY

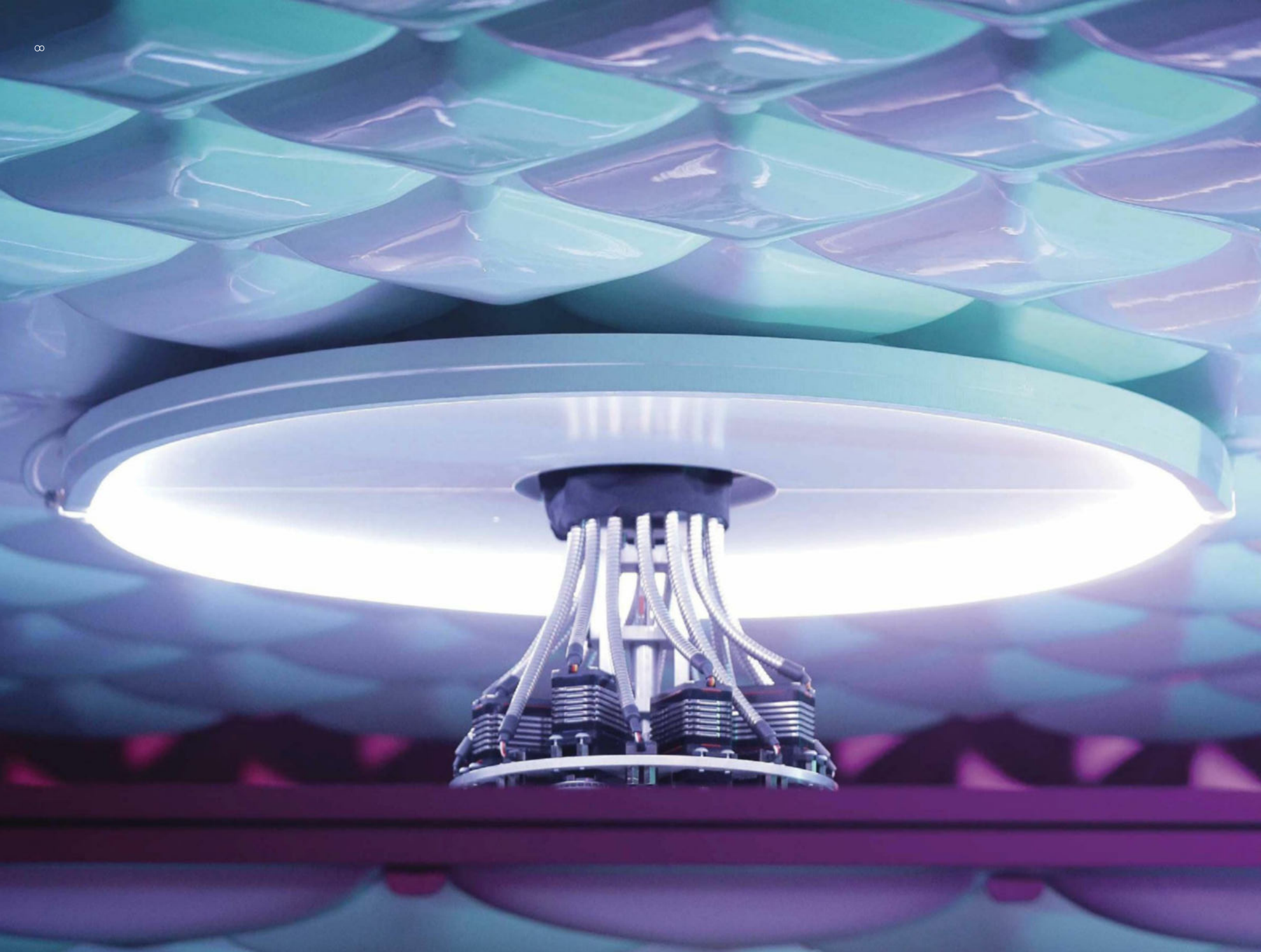
Peering through a hole in a poplar leaf, these two damselflies look ready to invite us in for a cup of tea. The pair, who appear to be holding hands, were spotted close to the river Po in northern Italy.

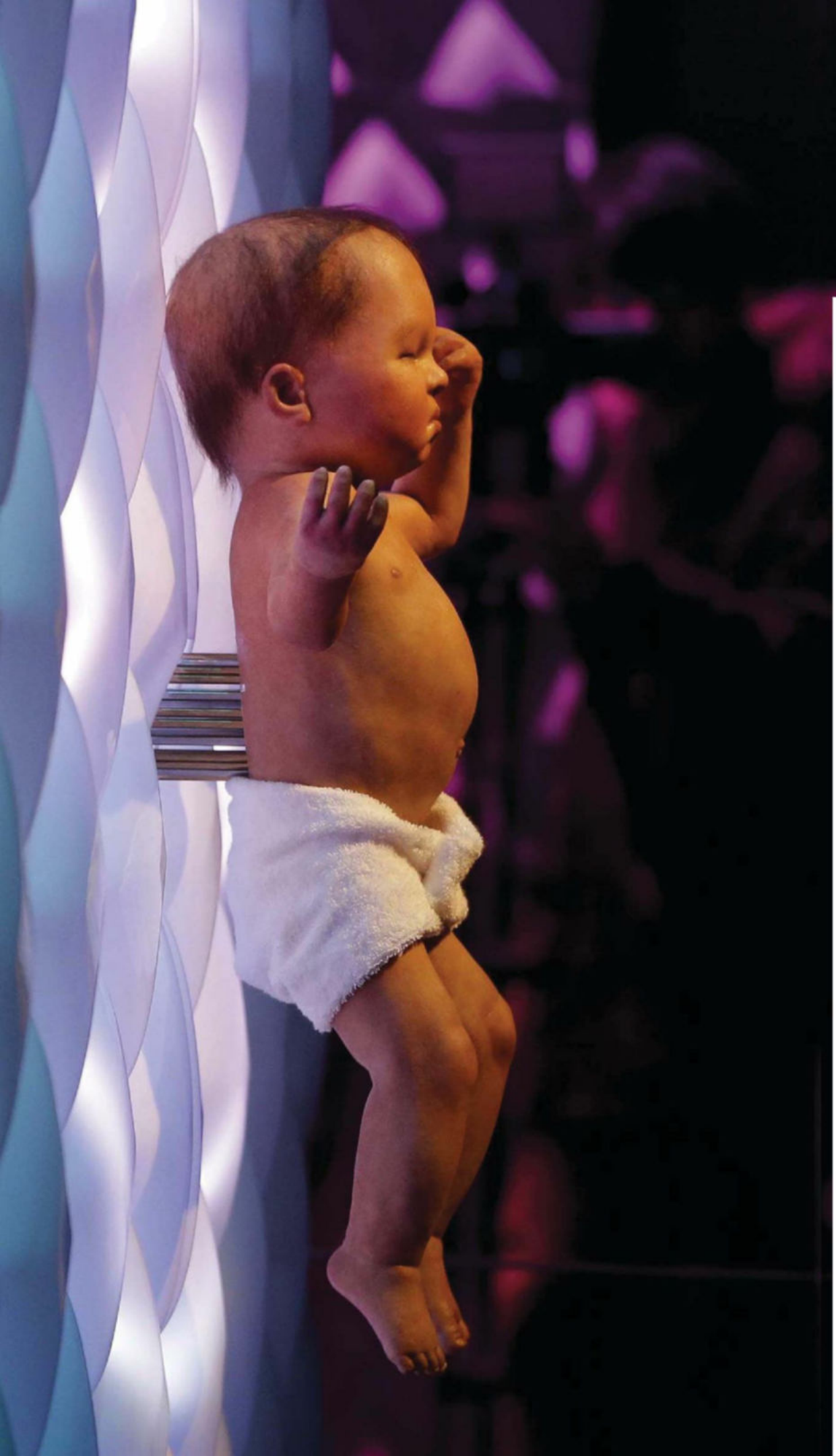
"Damselflies are often sexually dimorphic," says Prof Adam Hart, an entomologist at the University of Gloucestershire. "This means that the males and females differ, typically in size and colouration, with males often more colourful and smaller than females."

Here, the larger, green damselfly on the right is more likely to be the female, and she's probably been wooed by an elaborate courtship display. "The males will hover, flap, bob, flicker and display their wing spots in order to show themselves off," says Hart. "They'll also engage other males in 'flights of attrition', where the two rivals try to exhaust each other with aerobatics."

Once successful, the male will clasp the female behind her head, and the female will curve her abdomen around to pick up his sperm. The shape of the two mating damselflies often resembles a heart. Incredible!

PHOTO: R ALDROVANDI/SOLENT





Robo rugrat

LONDON,
UK

Visit the Robots exhibition at London's Science Museum and you'll be greeted by this little whippersnapper. The realistic, wall-mounted robot baby was built by UK animatronics company John Nolan Studio, and is based on the puppet babies they make for use on film sets. The puppets are usually operated remotely, but this one's been automated so that it runs through a routine of movements and expressions throughout the day – which is what the cables sticking out of the back are for.

Creepy near-realism aside, then, the baby is actually a low-tech affair. But that's the point: it's the first thing you see on a journey through 500 years of robot history, while the *last* thing you see will be an all-singing, all-dancing, high-tech AI robot toddler – symbolising both how far we've come, and how far we still have to go in the world of robotics.

"The exhibition is really about the human form as mechanism," says head curator Ben Russell. "So we wanted something that would capture people's attention and bring them into that headspace, before plunging them back to the 1500s to see automaton monks."

PHOTO: ASSOCIATED PRESS

FLARES®
PRO

Fall in love with music all over again

Introducing **FLARES® PRO.**
A new ***Bluetooth®*** wireless earphone
that produces sound quality so high,
every recording feels **live.**

*"These are the best earphones ever! I mix on these!
The detail, the clarity, and low end are
'pinch me am I dreaming' great."*

Tony Visconti

Grammy Award Winning Producer:
David Bowie, T-Rex, Morrissey, Iggy Pop

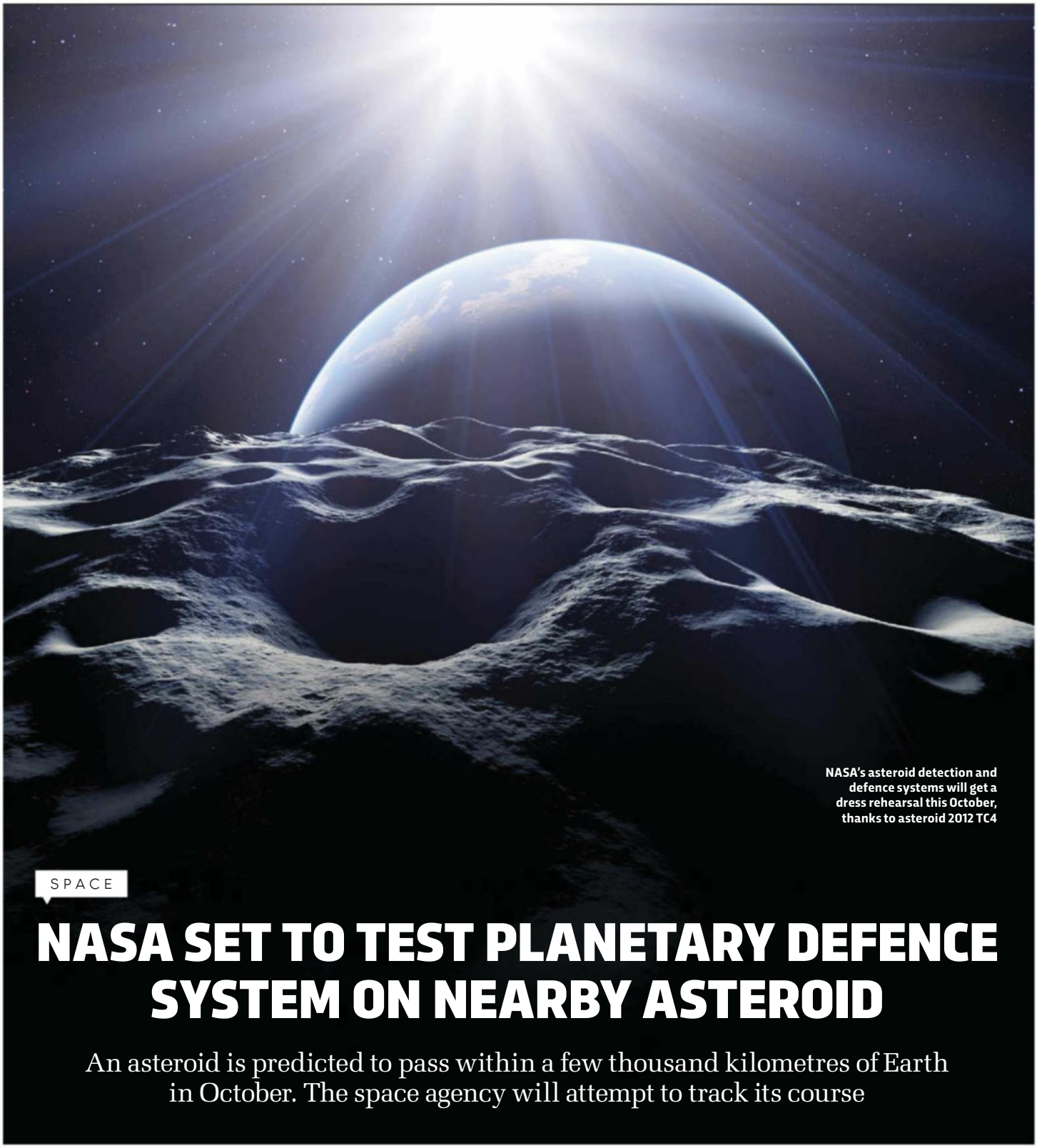
flareaudio.com

MADE IN GREAT BRITAIN

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

SEPTEMBER 2017 | EDITED BY JASON GOODYER



NASA's asteroid detection and defence systems will get a dress rehearsal this October, thanks to asteroid 2012 TC4

PHOTO: GETTY

SPACE

NASA SET TO TEST PLANETARY DEFENCE SYSTEM ON NEARBY ASTEROID

An asteroid is predicted to pass within a few thousand kilometres of Earth in October. The space agency will attempt to track its course

The path (green line) that the asteroid will take past Earth

The Pan-STARRS telescope in Hawaii first discovered the asteroid 2012 TC4

Bruce Willis has nothing on these guys: NASA scientists are gearing up to test out their planetary defence system when an asteroid the size of a double-decker bus whizzes past the Earth. Dubbed 2012 TC4, the space rock is expected to pass as close as 6,800km to the planet's surface on 12 October, giving space scientists a chance to trial planetary defence systems put in place should the Earth be in danger of being struck by an asteroid.

"Scientists have always appreciated knowing when an asteroid will make a close approach to and safely pass the Earth, because they can make preparations to collect data to characterise and learn as much as possible about it," said NASA's Dr Michael Kelley. "This time we are adding in another layer of effort, using this asteroid flyby to test the worldwide asteroid detection and tracking network, and so assess our capability to work together in response to any potential real asteroid threats that may be discovered in the future."

Asteroid 2012 TC4 is thought to be between 10m and 30m across, making it slightly larger than the space rock that hit Earth's atmosphere near Chelyabinsk, Russia in February 2013. It has not been seen since its discovery in 2012, when it sped past Earth at about a quarter of the distance from Earth to the Moon, as it has been too distant and too faint to be detected by ground-based telescopes. As it begins to approach Earth this summer, large telescopes will be used to detect it and re-establish its precise trajectory, in a move to improve tracking methods.

"WE KNOW THE ORBIT OF 2012 TC4 WELL ENOUGH TO BE ABSOLUTELY CERTAIN IT WILL NOT IMPACT EARTH"

"This is the perfect target for such an exercise, because while we know the orbit of 2012 TC4 well enough to be absolutely certain it will not impact Earth, we haven't established its exact path just yet," said researcher Paul Chodas.

Though there are no plans to attempt to actually change the trajectory of 2012 TC4, there are several ideas about how we could deflect an asteroid that was on a collision course with Earth. The simplest would be to crash a spacecraft of some kind into it to steer it to safety, but NASA has also been working on the idea of steering asteroids away by beaming them with lasers. The theory is that the laser would heat up the surface of the space rock enough for it to release gas, which would in turn create a thrust that would lead to changes in its path.

PHOTOS: NASA, BRITISH ANTARCTIC SURVEY

ENVIRONMENT

GIGANTIC ICEBERG SEPARATES FROM ANTARCTIC PENINSULA

The largest remaining ice shelf on the Antarctic Peninsula lost roughly 10 per cent of its area on 12 July. This is when an iceberg dubbed A68, which has an area around four times that of London, broke free.

Since then, researchers from the University of Leeds and the British Antarctic Survey (BAS) have been tracking the iceberg's journey using the European Space Agency's Copernicus Sentinel-1 satellite. They hope the event will offer them a unique opportunity to study the implications of the future loss of huge shelves of ice from the Antarctic. So far the iceberg has drifted 5km away from the Larsen-C ice shelf, shedding 11 smaller chunks of ice around 10km long as it went.

"The satellite images reveal a lot of continuing action. We can see that the remaining cracks continue to grow towards a feature called Bawden Ice Rise, which provides important structural support for the remaining ice shelf," said researcher Anna Hogg. "It looks like the Larsen-C story might not be over yet."

The team now intends to continue studying how the calving of huge icebergs like A68 affects the stability of Antarctic ice shelves and impacts on sea level rise.

"With this large calving event, and the availability of satellite technology, we have a fantastic opportunity to watch this natural experiment unfolding before our eyes. We can expect to learn a lot about how ice shelves break up, and how the loss of a section of an ice shelf affects the flow of the remaining parts," said researcher Hilmar Gudmundsson.

The calving of iceberg A68 reduced the area of the Larsen-C ice shelf by a dramatic 10 per cent

THE DOWNLOAD

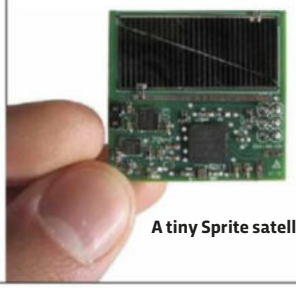
Breakthrough Starshot Sprites

Is that a new series on the Syfy channel?
Er, no. Breakthrough Starshot is a research project that aims to send probes beyond the Solar System, and Sprites are their new, tiny satellites.

Tiny satellites? We have those already, don't we?
Not this tiny. We've had 'cubesats' for a while, which measure just 10 x 10 x 10cm and weigh 1kg. But Sprites are in a new league of tininess: they're essentially 3.5 x 3.5cm printed circuit boards, and weigh just 4g each.

Sort of like a space-faring Raspberry Pi, then?
Sort of, but even smaller! Despite that, they carry all sorts of sensors and cameras, generate their own solar power and can communicate with Earth – as the first successful Sprite launches, piggy-backed on larger satellites, recently showed.

And why is that useful?
The smaller you can make space probes, the easier and cheaper it is to get them off the ground. It's hoped the technology used in the Sprites can be developed further to build space probes capable of reaching exoplanets within the next 40 to 50 years.



A tiny Sprite satellite

No new petrol or diesel cars will be sold in the UK from 2040 onwards, but will this really help reduce air pollution?

PHOTOS: TESLA, GETTY

IS BANNING THE SALE OF PETROL AND DIESEL CARS REALLY SUSTAINABLE?

Dr Stephen Hall, an academic fellow at the University of Leeds, weighs up whether the ban will clean up our cities for good

The most eye-catching part of the government's recent air-quality strategy is to ban sales of new petrol and diesel cars by 2040. This has polarised the debate around the sustainability of electric vehicles as the primary means of 21st-Century mobility.

The impetus behind the government's strategy is poor air quality: which is thought to be linked to about 40,000 premature deaths a year. The issue is that air quality limits in many UK towns and cities are breached regularly, and environmental campaigners, along with some city mayors, have been pushing for tighter controls on polluting vehicles.

But Client Earth, the campaign group leading the call for reform, has described the ban as "not enough". The group emphasises that clean air zones and sustainable transport infrastructures both work, and can be implemented more quickly. Even so, some argue that the target is too soon. The motor industry, however, does not argue that the cars won't be ready in time. This is unsurprising, given that Tesla already has an all-electric fleet, most manufacturers have at least one hybrid on sale, and Volvo recently committed to phase out all conventional engines by 2019.

The voices of dissent offer three main arguments: electric vehicles don't reduce greenhouse gas emissions; we don't have enough power available; and there are not enough critical materials like lithium which underpin most new electric vehicle battery technologies.

The first two arguments are closely related. The problem is not the absolute volume of electric vehicles on the road but when we charge them. The issue is 'peak demand' – the period, usually of one to three hours, when the most electricity is being used. We design our electricity-

Tesla's Model X offers a 416km (258-mile) range

"ELECTRIC CARS ARE NOT A PANACEA. THEIR POWER SOURCE NEEDS CAREFUL MANAGEMENT"

infrastructure systems, markets and power provision largely to ensure these peaks are covered. Peak demand in the UK is between 5pm and 7pm in winter. This is usually when electricity is at its most 'dirty', or polluting, as this is when we need almost all of our generating capacity, including the old coal plants, diesel back-up generation and gas. Without managed charging, drivers plugging the car in on return from work face using diesel engines and coal-derived power to charge vehicles. Hardly a win for air quality or climate change.

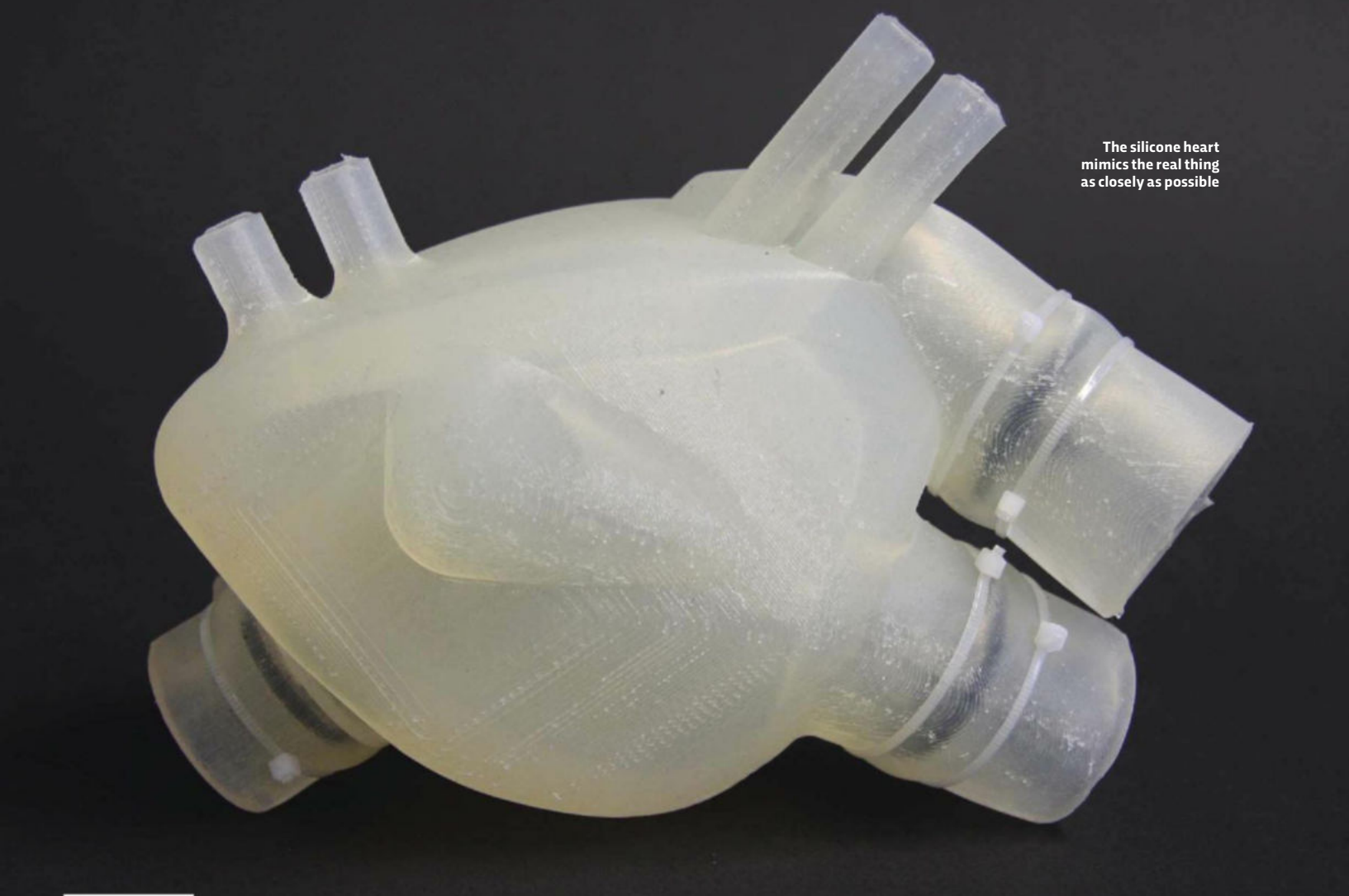
National Grid estimates that electric vehicles could add up to 8GW of demand at peak times by 2050, which is a little more than twice the capacity of the Hinkley C nuclear reactor. However, this figure could be brought down by adopting managed charging, to move charge cycles to after the evening peak.

The last problem, material availability, is a trickier prospect. Lithium, cobalt and the rare earth metals used in electric vehicles present several problems. It's not only a question of whether there are enough of these materials, but also their toxicity, ease of recycling and – perhaps most pressing in the short term – their geopolitical availability and the ethical acceptability of their supply chains. Much like the issue of peak demand, without strong policy and behavioural and technical advances, we could easily see the onset of global conflict, ecocide and exploitation around the critical materials for electric mobility, just as we have for petrochemical mobility.

While a ban on petrol and diesel car sales in 2040 is easily achievable, what really matters is how well the above issues are dealt with, as this will define whether electric mobility is a sustainable transition or just creates further problems.

Electric cars are not a panacea. They do nothing for congestion, their power source needs careful management, and their supply chains may be no less problematic than those of petrochemical fuels. Conversely they can reduce air pollution, act as a smart grid resource, and help meet climate change commitments. Like many technical solutions they need strong governance and regulation around them. We should use the current debate to improve our dialogue on electric mobility, seeking clear government policy on energy market integration and strong standards on material sustainability.

Dr Stephen Hall is based at the School of Earth and Environment at the University of Leeds. His research focuses on deep decarbonisation of cities, energy, economics and low carbon futures



The silicone heart mimics the real thing as closely as possible

BIOLOGY

NEW ARTIFICIAL HEART GETS CLOSER TO NATURE

Proving that medical researchers can be soft-hearted too, a team at the Swiss Federal Institute of Technology in Zurich has used malleable silicone and 3D printing to create the most human-like artificial heart to date.

It's just 60 years since the first heart patients were given pacemakers, and 50 since the first human heart transplant took place. So while these procedures are almost considered routine, the technology involved is still in its relative infancy. The artificial hearts currently given to patients awaiting a transplant use mechanical pumps, which can seize up or fail; they also leave the patient without a natural pulse, which can affect other bodily functions. The new heart, in contrast, replaces the mechanical pump with an additional chamber that is inflated and deflated by pressurised air, mimicking a heart's muscle contractions and generating a realistic pulse.

"Our goal is to develop an artificial heart that is roughly the same size as the patient's own, and which imitates the human heart as closely as possible," said researcher Nicholas Cohrs.

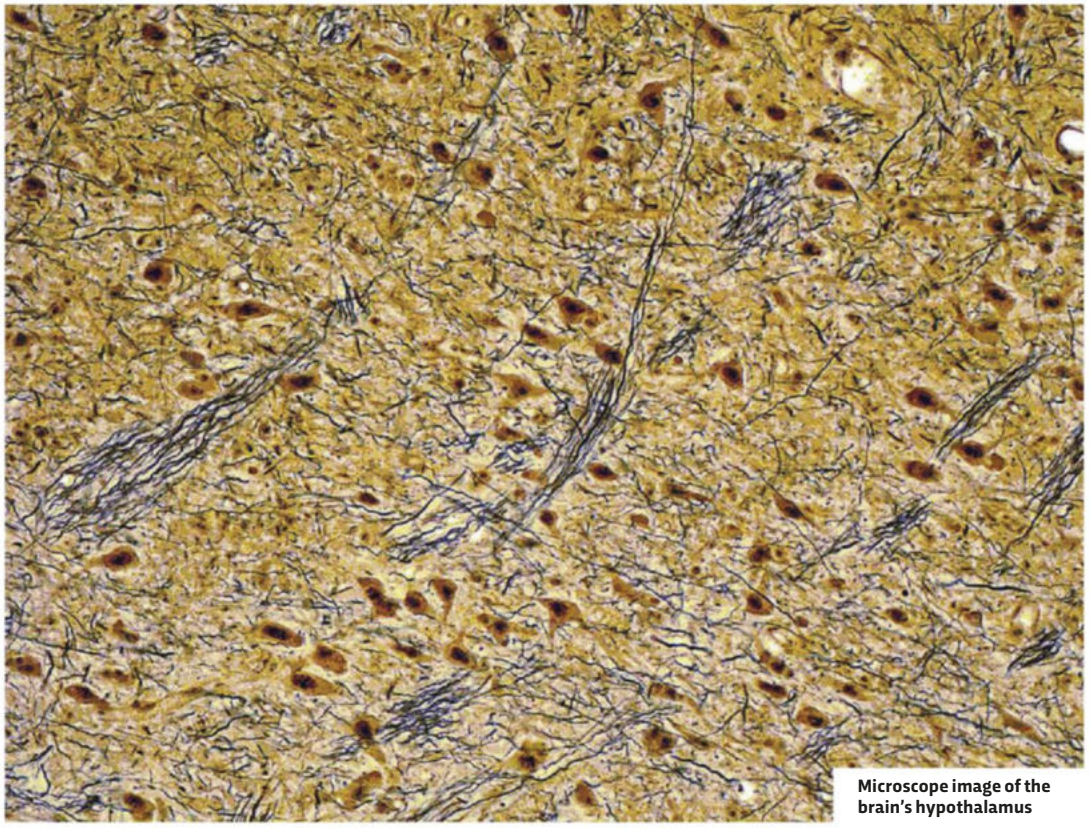
The heart developed by Cohrs and his team has been proven to work; the catch is that it only lasts for around 3,000 beats, or roughly half to three-quarters of an hour.

"This was simply a feasibility test," explained Cohrs. "Our goal was not to present a heart ready for implantation, but to think about a new direction for the development of artificial hearts."

PHOTOS: ZURICH HEART, SCIENCE PHOTO LIBRARY, BREAKTHROUGH STARSHOT

NEUROSCIENCE

BRAIN'S AGEING MECHANISM DISCOVERED



Microscope image of the brain's hypothalamus

It's official: ageing is all in the mind. But when we say 'the mind', we mean 'the brain' – and specifically the hypothalamus, a region of the brain that is involved in growth, reproduction and metabolism. In 2013, researchers at the Albert Einstein College of Medicine in New York proved that this region of the brain also governs the entire body's ageing process – and now the same team has identified the precise mechanism involved.

The mechanism lies in a small cluster of neural stem cells, which were already known to be responsible for the formation of new brain neurons. The number of these stem cells declines as we get older, but the team has shown that by injecting fresh stem cells into the brains of adult mice, the ageing process can be delayed or even reversed.

Before they could get to that point, the researchers first had to prove that these were indeed the cells responsible for ageing, which they did by selectively destroying such cells in the brains of middle-aged mice.

"This disruption greatly accelerated ageing compared with control mice, and those animals with disrupted stem cells died earlier than normal," said Dr Dongsheng Cai, who led the research. The researchers then tried injecting new stem cells into this region in the brains both of middle-aged mice whose stem cells had been previously destroyed, and of older mice. The injections produced exactly the kind of anti-ageing effects they'd anticipated.

The team has further shown that the stem cells work their anti-ageing magic by releasing molecules called microRNAs, which affect gene expression, and which the stem cells release into the spinal fluid inside tiny particles called exosomes. It's now hoped that new treatments for age-related diseases in humans can be developed, based upon injection of exosomes into the hypothalamus.

IN NUMBERS

30

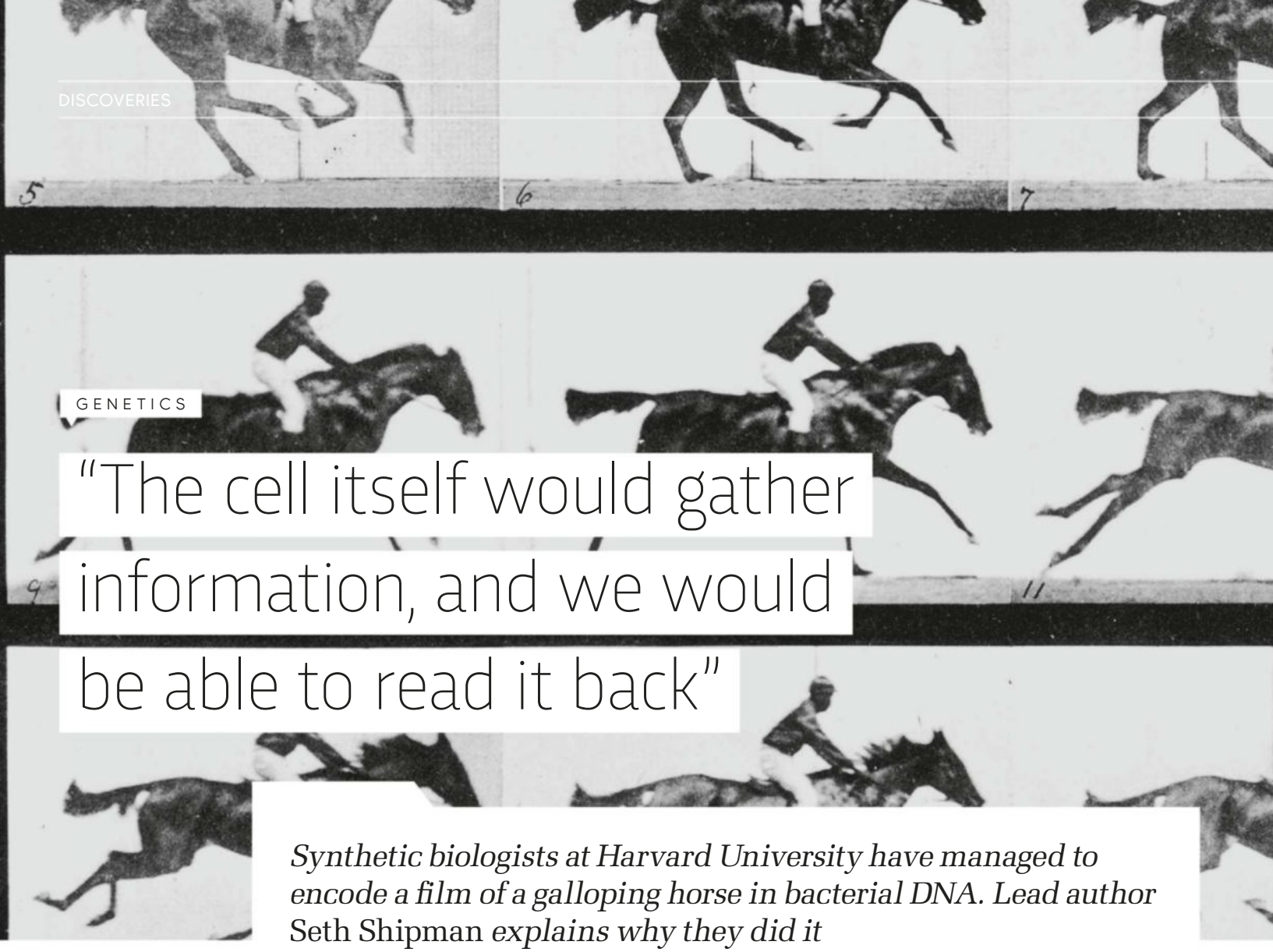
The number of vaquitas, a type of porpoise found in the Gulf of California, left in the wild. This makes them the most endangered marine mammal on Earth.

1 QUINTILLION

The number of calculations China's Sunway TaihuLight supercomputer is capable of. That's 1 with 18 zeroes after it.

150 MILLION

The number of lives at risk due to increases in carbon dioxide in the atmosphere reducing the amount of protein found in staple crops such as rice and wheat, researchers at Harvard University say.



GENETICS

"The cell itself would gather information, and we would be able to read it back"

Synthetic biologists at Harvard University have managed to encode a film of a galloping horse in bacterial DNA. Lead author Seth Shipman *explains why they did it*

ABOVE: **Eadweard Muybridge's famous images of a galloping horse have been encoded into DNA to make a film**

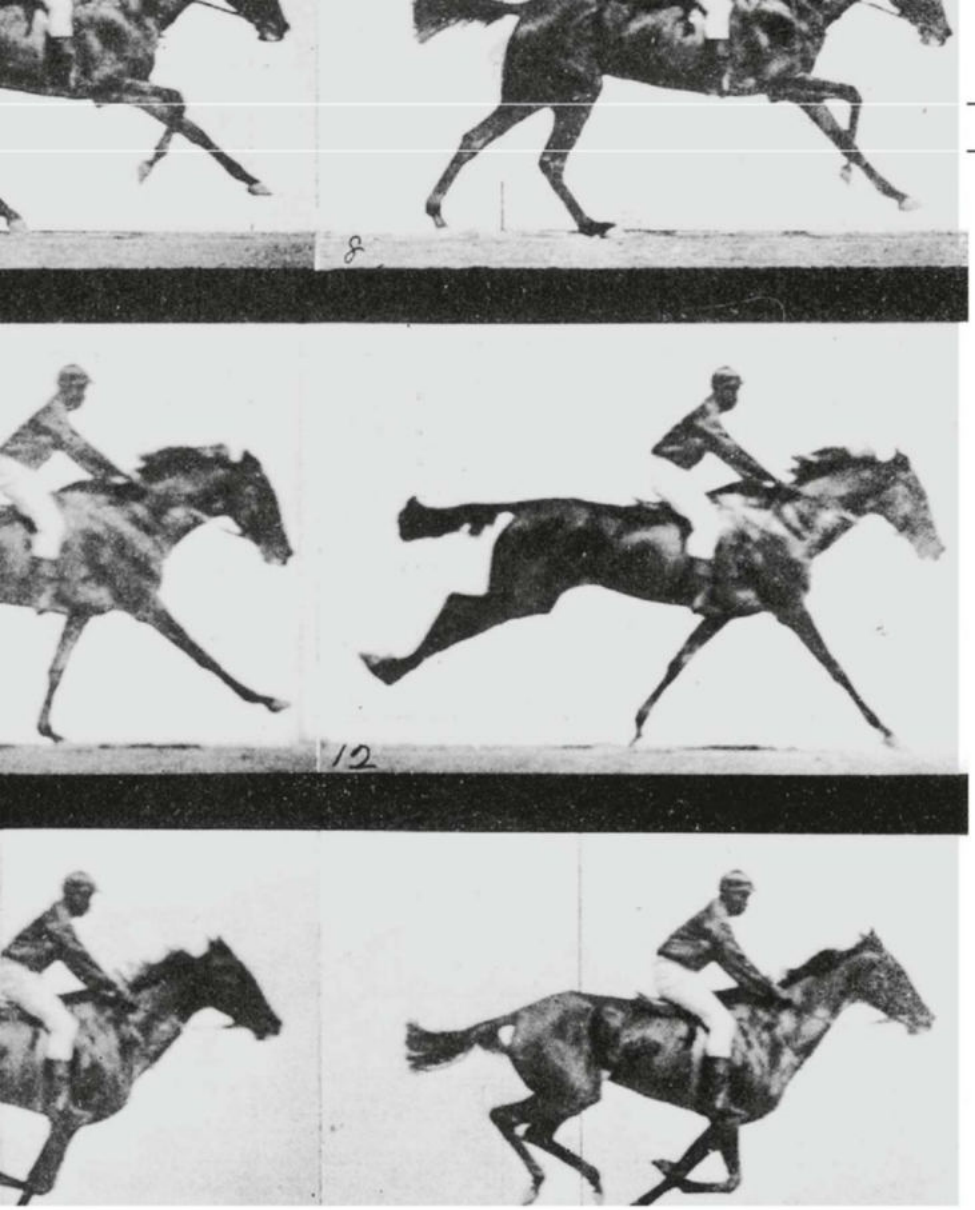
Why save moving pictures of a galloping horse in DNA?
We're trying to create a living 'molecular recorder' – a cell that would capture information and store it in the DNA bases [the letters A, C, G and T] of the cell's own genome, and get that information back again by sequencing the cell [reading its DNA]. We did all this in *E. coli*.

How do you encode images as DNA letters?
You have a bunch of pixels, and each pixel has a different value on a greyscale of black or grey or white. We came up with a code that says each pixel value would be a combination of three DNA bases, in one case, 'CTG' might encode a medium grey. We used three bases instead of a single base because that's how cells code for the amino acids that make up proteins.

How do you write movies to DNA?
The system we're using is based on CRISPR, an immune system that bacteria use to defend themselves from viruses. When a virus puts its genome into a cell, two proteins – Cas1 and Cas2 – grab a chunk of that viral DNA and insert it into the cell's genome. This serves as a memory. The cell is immunised, using that sequence to guide an enzyme – Cas9 – to cut up the virus. We're using that first part of CRISPR: we code pixel values, synthesise DNA and deliver it to cells making Cas1 and Cas2. Those two proteins then grab the pieces of DNA and put them into one spot in the cell's genome. The information gets copied every time the cell divides. We took all DNA that encoded pixel values for the first frame [of a movie] on one day, let the bacteria grow overnight, then provided the second, and so on until we'd done all five frames in order. When the CRISPR system inserts new DNA into that one spot, it goes to the beginning, everything else moves down.

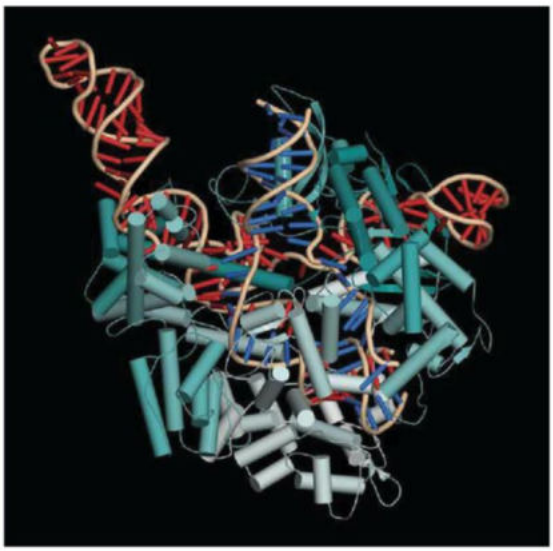
How do you read the movie from DNA?
We take a sample of cells, break them open and sequence [read] just that one spot in their genome. We look at what the DNA says each pixel should be, but the physical arrangement in the genome also gives us time information. If you look at the images that are reconstructed, some pixels are 'noisier' – these are ones where information was never captured or we got the timing a bit wrong. It's not quite perfect.

PHOTOS: GETTY X2. ILLUSTRATION: DAN BRIGHT



What makes 'molecular recorders' useful?
Information storage in DNA is a growing field and it has potential to be used for archive-quality storage. But we'd like to hook aspects of this system up to sensors for things within a cell or in its environment. The cell itself would gather information, and we would be able to read it back in the same way as we were able to reconstruct that movie. So bacteria could be living in soil, or in a stream, and sense contaminants or pollutants. It doesn't require power, and we can just sample the cells and get instantaneous information, but also find out what's been happening over time.

BELOW:
The Cas9 enzyme (green and grey) using a guide (red) to cut a DNA sequence (blue)



Watch the team discuss the research at **bit.ly/CRISPR-horse**

THE WEALTHY
Money *can* buy you happiness. A team at Harvard Business School has found that buying free time, by hiring a cleaner, for example, can lower stress and improve life satisfaction.

THE NEUROTIC
Despite living with the constant worry, those with neurotic tendencies outlive calmer characters, a team at the University of Edinburgh has found. The effect could be down to neurotic people being more careful.

GOOD MONTH

BAD MONTH

THE EARTH
2 August was Earth Overshoot Day, the day on which we used up planetary resources such as water, soil and clean air for the year. We will be living 'in credit' for the rest of 2017.

LONG DISTANCE DRIVERS
Driving for more than two or three hours a day can make you less smart, a team at the University of Leicester has found. It could be due to the mind being less active when driving.

We urgently need to cut fossil fuel consumption to reduce global warming

ENVIRONMENT

THE EARTH WILL ALMOST CERTAINLY BE 2°C WARMER BY 2100

In December 2015, the Paris Agreement, which has been signed by 195 countries, pledged to take action on global warming. The Agreement aimed to limit worldwide temperature rises to less than 2°C above pre-industrial levels by 2100, and to endeavour to keep it below 1.5°C. But new research from the University of Colorado suggests that hitting those targets may be much harder than previously thought.

"The window of opportunity on a 1.5°C target is closing," said lead researcher Dr Robert Pincus.

The team used no computer modelling in their research, instead relying entirely on real-world measures of climate change. They discovered that even if we cut fossil fuel emissions to zero tomorrow, we are already committed to warming of around 1.3°C by 2100. If we fail to act, and emissions remain at their current levels for another 15 years, then a temperature rise of 1.5°C is inevitable.

There is *some* room for doubt here: the effects of carbon sequestration by the oceans could reduce those figures by as much as 0.4°C. Even so, Pincus estimates that the likelihood of 1.5°C of warming occurring by 2100 is currently around 13 per cent – and rising all the time.

PHOTOS: GETTY, NASA/HUBBLE SPACE TELESCOPE ILLUSTRATION: DANIEL BRIGHT

SPACE

HALF OF THE MATTER IN THE MILKY WAY COMES FROM OTHER GALAXIES

It seems we are all intergalactic travellers. Around 50 per cent of all matter in the Milky Way originated in a different galaxy, new research has revealed.

It has long been believed that once galaxies start to form, they keep to themselves, with the matter that coalesced to form a galaxy in the first place essentially staying in it forever. But a new study carried out at Northwestern University in Illinois suggests that matter is, in fact, regularly transferred from one galaxy to another.

"Given how much of the matter out of which we are formed may have come from other galaxies, we could all consider ourselves space travellers, or extragalactic immigrants," said study co-author Daniel Anglés-Alcázar.

The Northwestern team used computer models to study the evolution of the Universe from just after the Big Bang, up to the present day. Their models showed that when a supernova occurs, large amounts of matter can be ejected from the host galaxy, and can traverse space in the form of an intergalactic wind before eventually being subsumed into another galaxy up to a million light-years away.

It's generally a one-way street, though, with gas and dust transferred from small galaxies to larger ones, rather than the other way round. This process of 'intergalactic transfer', as it's been dubbed, is a new discovery, and means much of our understanding of galaxy formation and evolution may need to be reconsidered.

Galaxies steal matter from other galaxies

THEY DID WHAT?!

WHALES' SONGWRITING SKILLS STUDIED

What did they do?
A team at the University of Queensland listened in on the songs of a population of humpback whales, taking note of how the patterns, or verses, within them changed over time.

What did they find?
All males within a group sing the same song. However, the patterns change over time as they are altered by individual whales. Other whales in the group then learn these new verses and the new version, or remix, of the song quickly spreads through the group.

Why did they do that?
The study provides firm evidence of how animals learn complex behaviours and may help shed light on the evolution of human language, the researchers say.

GENETICS

TARDIGRADE GENOME SEQUENCED

DNA sequencing should shed new light on a tardigrade's amazing powers of endurance

As some of nature's toughest critters, despite measuring less than 0.5mm long when fully grown, tardigrades can survive dehydration, extreme temperatures, the vacuum of outer space and doses of radiation hundreds of times stronger than that required to kill a human. Now, a team from the University of Edinburgh has sequenced the genomes of two species of tardigrade in an attempt to understand exactly how they are capable of such feats.

By exploring the animals' DNA, the team identified the genes that enable tardigrades to resist the effects of dehydration. These genes activate as the animals dry out, triggering the production of proteins that replace the water in their cells and preserve the microscopic structure. Other proteins analysed appear to protect the tardigrades' DNA from damage, and may explain why they can survive such high levels of radiation. The researchers were also able pinpoint the animals' exact position in the tree of life. It turns out that they sit between arthropods, such as insects and spiders, and nematodes, a type of roundworm.

The researchers hope that further study of the genome will enable them to develop medicines and therapies for use on humans.

"I have been fascinated by these tiny, endearing animals for two decades. It is wonderful to finally have their true genomes, and to begin to understand them," said research lead Mark Blaxter. "This is just the start: with the DNA blueprint we can now find out how tardigrades resist extremes, and perhaps use their special proteins in biotechnology and medical applications."

PHOTO: KAZUHARU ARAKAWA/HIROKI HIGASHIYAMA

THINGS WE LEARNED THIS MONTH

YOGA CAN HELP FIGHT DEPRESSION

Researchers in San Francisco have found that twice weekly sessions of yoga helped to relieve the symptoms of depression in just eight weeks. *Om...*

T. REX COULDN'T HAVE OUTRUN HUMANS

Looks like *Jurassic Park* got another thing wrong. German researchers have calculated the king of the dinosaurs' top speed to have been around 16mph – not fast enough to catch a speedy human.

SLEEPING TOO MUCH CAN GIVE YOU NIGHTMARES

Do you often dream of losing all your teeth, or being chased by a wolf? Getting more than nine hours of shut-eye a night can increase your chances of having bad dreams, a team at the University of Oxford have found.

SPERM COUNTS OF WESTERN MEN ARE DECLINING

A meta-analysis at the Hebrew University of Jerusalem looking at over 100 studies has found that sperm concentration has fallen by more than 50 per cent since 1973.

WE NEED TO START LISTENING TO THE MAVERICKS

Sometimes scientific breakthroughs come from the most unexpected places

What would you make of this puzzle, which reared its head 50 years ago this month? A radio receiver near Cambridge picked up faint bursts of energy which appeared daily, as regularly as clockwork. Well, almost: they turned up four minutes earlier each day.

That four-minute difference was a big clue: it suggested the radio waves weren't coming from Earth. That's because the world spins once on its axis every 23 hours and 56 minutes relative to the stars – four minutes shorter than a day as measured by a clock.

Using more sensitive recorders only deepened the mystery. The bursts of energy looked more like signals, repeating every 1.3373 seconds. Graduate student Jocelyn Bell and her colleagues started to wonder if they'd discovered the first signs of alien intelligence.

Publication of the discovery sparked a flurry of explanations. Bell and her colleagues suggested it might be a kind of vibrating star, but within a few weeks, the correct explanation had been found. It was a rapidly-spinning remnant of a supernova explosion known as a pulsar.

Its identification as the source of the energy was one of the biggest breakthroughs in 20th-Century astronomy. Yet it had been made by someone with no formal training in the subject, who nearly flunked his degree and never bothered to get a PhD – Tommy Gold.

Born into a wealthy Austrian family in 1920, Gold came to Cambridge where his quirky intellect was noticed by two brilliant university dons, Hermann Bondi and Fred Hoyle. One night, the three of them saw a movie whose storyline formed an endless loop – prompting Gold to wonder if the history of the Universe could do the same. This led them to devise the so-called Steady State theory of the Universe, which argued that the cosmos had existed forever, the Big Bang being replaced by a force field which propelled the expansion.

"RESEARCH TODAY IS DOMINATED BY THE SEARCH FOR BANDWAGONS, NOT BREAKTHROUGHS"

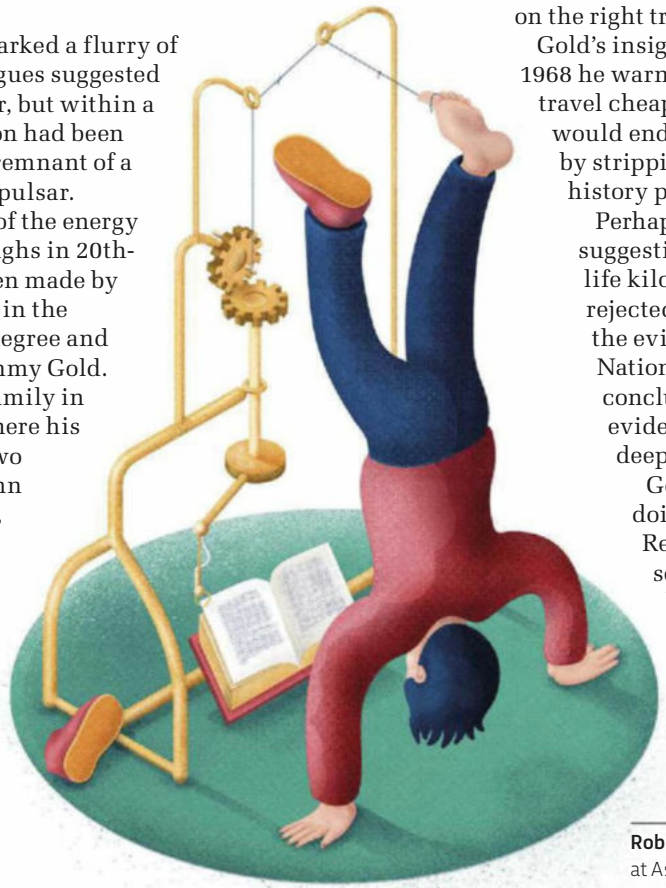


ILLUSTRATION: DANIEL BRIGHT

While debunked by the discovery of the heat left over from the Big Bang, the Steady State theory forced astronomers to test their ideas more thoroughly. Its proposal of a cosmic force field also presaged dark energy, which is now at the centre of cosmological research.

But this was just the start of Gold's career as a scientific maverick. While still a student, he'd pondered the mystery of how the human ear can distinguish musical notes so accurately. He decided the textbook explanation – that the brain does all the hard work – was wrong, and predicted the existence of amplifying structures within the cochlea. In what became a regular feature of his career, Gold's idea was initially dismissed by experts, but years later the discovery of cochlear hair cells showed he'd been on the right track after all.

Gold's insights often got him into trouble. In 1968 he warned that NASA's plans to make space travel cheap and routine using space shuttles would end in disaster. The agency responded by stripping Gold of his research funding, but history proved him all too prescient.

Perhaps Gold's craziest idea was that his suggestion that the Earth is teeming with life kilometres below the surface. Initially rejected as ludicrous, the latest review of the evidence, published by the US National Academies of Science this year, concluded there is now "overwhelming evidence" for vast colonies of bacteria deep inside the Earth.

Gold died in 2004, but his way of doing science expired years earlier. Research today is dominated by the search for bandwagons, not breakthroughs. Quirky ideas are regarded as dangerous detours on the road to grants. But without letting mavericks like Gold suggest alternative routes, science risks going round and round in circles.

Robert Matthews is visiting professor in science at Aston University, Birmingham.

DIVING DEEPER

TRITON 7500/3
PRICE: $6.3m (£4.8m approx)
tritonsubs.com

Intended as leisure vehicles for superyacht owners, Triton Submarines' mini submersibles have proved a surprise success with marine researchers and wildlife film-makers. So Triton is now building tougher subs that can dive deeper than ever.

Building submersibles that can reach great depths isn't that hard; the tricky part is designing one that can withstand the huge pressures involved, yet still has a screen that you can see out of. Accordingly, Triton's latest machines feature a viewing dome made from a 261mm-thick globe of acrylic glass, which means the current two-seater 7500/2 and three-seater 7500/3 subs can descend to around 2,300m, compared to the few hundred metres earlier subs could manage.

Triton hopes eventually to produce a submersible, complete with viewing dome, that can reach the very deepest parts of the ocean.

1

2

3

4

5

WANTED

1

PONG ELIMINATOR

No one wants to walk round honking to high heaven, but for those with a tendency to BO, monitoring one's olfactory 'presence' can be a tad embarrassing. Waving an odour-detecting Bluetooth device under your arms is, of course, *far* more discreet...

Kunkun Body
¥30,000 (£205 approx), konicaminolta.jp

2

CINEMATIC SMARTPHONE

This Android smartphone comes from RED, who make professional movie cameras. Its main draw is a 5.7-inch holographic display that shows 3D, virtual, mixed and augmented reality content. There's also a USB-C port, microSD slot and a headphone jack.

RED Hydrogen One
From $1,195 (£915 approx), red.com

3

A QUICK BRUSH-UP

Many of us don't brush our teeth for long enough. This gumshield-like device, currently on Kickstarter, aims to solve that by reducing the time required for a thorough clean to 10 seconds. Its fast-moving bristles apply a toothpaste as they go.

Amabrush
$TBC, amabrush.com

4

PONG PROVIDER

This Christmas's hottest console will be… an Atari. No, really! The company that started it all is getting back in the game with the Ataribox, which promises to combine retro styling and thoroughly modern specs – though the latter are still TBA.

Atari Ataribox
£TBC, atari.com

5

CYCLE SMART

Know a Lycra-clad cyclist who has everything? Bet they don't have a pair of AR glasses that display their heart rate, ride stats and maps on a virtual heads-up display! These Raptor specs are the ultimate in eyewear-based showing-off…

Everysight Raptor
£TBC, everysight.com

6

SCOUT AND ABOUT

This 'pedal assist e-bike' has a 250W motor, a top speed of 25km/h and a range of 32km, not to mention chunky tyres and styling that Action Man would be proud of. Best of all, you can ride one on UK roads without a licence…

Super Scout 73 Europe
£753.98, lithiumcycles.com

6

A HOME FROM HOME

The Marco Polo camper arrives on UK shores...

MERCEDES BENZ V-CLASS MARCO POLO V250 D LONG

PRICE: £55,055

mercedes-benz.co.uk

SPEC:

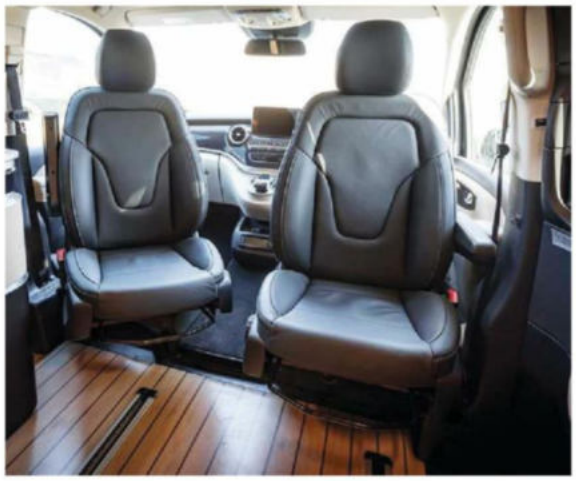
FUEL CONSUMPTION: 44.MPG (CLAIMED)

0-60MPH: 9.6 SECS

BHP: 190

CO_2: 169G/KM

ENGINE: 2.5L DIESEL



DRIVE

To the uninitiated van driver, the Marco Polo is reassuringly simple to pilot, despite being almost 2m tall and 5m long. The soft suspension takes most of the roll out of the roads and soaks up sharp bends – to a point. The most prescient reminder you'll get that you've brought the kitchen sink with you is if you have to test the brakes at the traffic lights. Otherwise the 2.5-litre engine does a stoic job of tugging your home from home to your holiday destination. You can fearlessly point the Marco Polo to the other side of Europe, and take on all the motorways, mountain climbs and switchbacks the continent might throw at you, albeit at a leisurely pace. And once you arrive, sensors and cameras make light work of parking. The only wobbles we experienced were courtesy of a blustery motorway, which made the van lean slightly.

INTERIOR

The Marco Polo cuts a monolithic silhouette against campsites dotted with retro VW camper vans and bell tents. Behind the tinted windows the cabin is satisfyingly ostentatious too, with panels gleaming with chrome and a floor decked with wood. The layout will be familiar to anyone who's seen a VW California: fridge, hob and sink from left to right with a fold out table and front seats that swivel round to face the rear. But the Marco Polo feels like it goes that little bit further. We were still finding compartments days into our test and there's even a mini-wardrobe. With the roof up the canvas is breathable but strong enough to keep the inevitable British summer storms at bay. The awning is simple to deploy and just as easy to pack away once the rain starts. When it does pour, the camper is cosy enough to spend the night tucked under a blanket.

TECH

The Marco Polo is kitted out with the typical Mercedes infotainment system, but the tech really comes alive when the car is stationary. The roof rises electrically at the flick of a switch, and packs itself away simply too – without snagging the canvas. In the roof, which you access by gingerly climbing up via the front seats, there's a USB socket that's wired into the car's stereo so you can enjoy your music up there. The bed downstairs is similarly effortless to set up. After sliding it along the cabin, two buttons command the rear seats to electrically fold back and suction the cushioning out of the upholstery to even out the 'mattress'. When the Sun sets, you're never more than an arm's length from an LED reading light, and if it gets cold you can flick the heating on from the key fob or schedule it to come on during the night.

VERDICT

If you find yourself overcome with wanderlust, the Marco Polo will scratch that itch. It feels like a professional and practical tool for touring the continent. At over £55,000, it's undeniably expensive – that's seven-seater Land Rover money. But the Land Rover doesn't come with a kitchenette and a second bedroom. The camper van is likely to hold its value a little better too. If you're taking kids with you, you'll be clenching your fists when little feet bring dirt, mud, sand and grass into the luxurious interior. Ultimately, though, this is a camper for those who want to escape into the wilderness, but don't entirely want to leave civilisation behind. **8/10**

ENTERTAINMENT

BEATING THE TOUTS WITH ULTRASONIC SOUND

With 'secondary ticketing' a major bone of contention in the entertainment industry right now – the practice has even been the subject of questions in Parliament – online ticket agency Ticketmaster has come up with a novel solution involving your smartphone and ultrasonic audio.

Ticket touts (or 'scalpers' if you're in the US) have been around forever, buying tickets for concerts or sporting events early and then selling them on at a mark-up nearer the time. The dawn of the internet era, however, means 'secondary ticketing' is no longer the preserve of a few scruffy chancers standing in the rain outside your nearest arena, but rather a multimillion-dollar industry that's making it hard to get event tickets at face value at all.

Ticketmaster's solution involves replacing the paper ticket with a system called Presence. Developed with data-via-audio company Lisnr, Presence sends a series of unique, identifying tones in the 18.7-19.5kHz range (right at the upper threshold of human hearing) to your smartphone, which your phone then relays to sensors at the venue when you arrive. This should not only help ensure that the person at the concert is actually the person who bought the ticket, but also help reduce queuing times. It's the same technology used by high-end vehicles from Jaguar and Land Rover to identify different drivers and automatically adjust the driving seat for them when they get in.

The Presence system can also track the location of individuals within a venue, which could have beneficial security applications – just don't be surprised if you find it's used for the delivery of 'targeted' advertising straight to your pocket.

TECH BYTES

MARSUPIALS VS VOLVO

Australians may have to wait a little longer than most for self-driving cars. Volvo has gone Down Under to test its autonomous vehicles, and has found that while their AI navigation systems can cope with most eventualities, bouncing kangaroos confuse the hell out of them...

VR FROM THE BBC

Keeping track of all the BBC's experiments around virtual, mixed and augmented reality can be tricky. That's why the BBC Taster website was launched – and now there's an accompanying app for your iOS or Android device. Get it at **bbc.co.uk/taster**

RIP, WINDOWS PHONE

In news that will upset lovers of clunky, unresponsive tile-based interfaces everywhere, Microsoft is no longer supporting its Windows Phone 8.1 smartphone operating system. Most existing users will, however, be able to upgrade to Windows 10 Mobile.

ROBOTS

ROBOCOP BECOMES A REALITY

If you're visiting Dubai from 2018 onwards, behave yourself – because autonomous police vehicles will be watching your every move.

Dubai Police recently purchased an REEM robot from Spain's PAL Robotics that acts as a kind of automated police officer, but now they're going one step further with the introduction of a fleet of O-R3 robotic police vehicles from Singapore-based OTSAW Robotics. While the REEM robot is built to handle mundane tasks, such as allowing people to report low-level crimes or pay their traffic fines, the O-R3 cars will actually patrol the streets to look out for criminal behaviour and keep an eye on known wrongdoers.

Each car is accompanied by its own aerial drone, and between them the two pieces of hardware are kitted out with an impressive array of gadgets beyond those required for simple navigation. These include cameras that can be used for thermal imaging, stereo imaging and facial and licence plate recognition, 2D and 3D laser scanners, GPS, long-range data transmitters, and more. They also come with advanced machine learning, to help the O-R3 (and the human beings monitoring its data feed at the station) make sense of it all.

You're not likely to find yourself hurtling past the Burj Al Arab in a *Starsky & Hutch*-style car chase, though. Human operators *can* take remote control of the vehicles if necessary, but their primary role is as a deterrent, to make people think twice about breaking the law in the first place. The first O-R3 vehicles are expected to head out on patrol later this year.

Each tiny (and pretty darn cute) robot car works with an aerial drone to track down criminals

SOLAR POWER GETS AN EFFICIENCY BOOST

With the need to generate power without burning fossil fuels growing ever more urgent, news that researchers at George Washington University (GWU) in Washington, DC have invented a new type of solar panel that is almost twice as efficient as existing panels is very welcome.

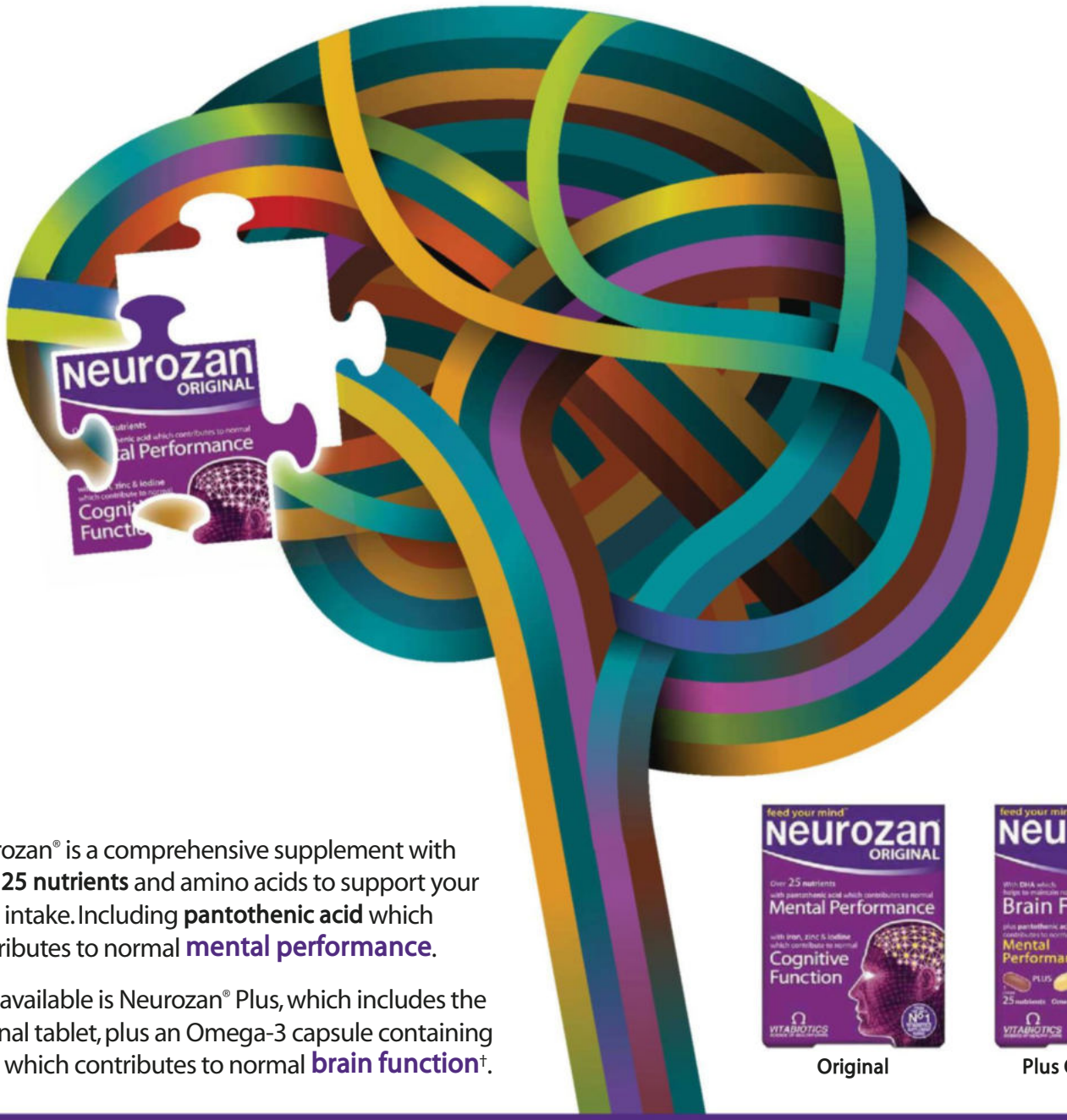
Funded by a $900,000 grant from the Advanced Research Projects Agency's energy division and led by Matthew Lumb from GWU's School of Engineering and Applied Science (as well as the Naval Research Laboratory), the team's new panels can convert sunlight energy into electricity with an efficiency of 44.5 per cent, compared to 25 per cent for existing panels. They do this partly by using a type of technology that allows multiple solar receivers to be stacked one on top of another within a single cell, and partly by employing new materials derived from gallium antimonide substrates that are normally used in infrared lasers. Together, these two technological improvements allow the solar cells to capture a wider swathe of the sunlight spectrum and convert it into electrical energy.

"Around 99 per cent of the power contained in direct sunlight reaching the surface of Earth falls between wavelengths of 250 nanometres and 2,500 nanometres, but conventional materials for high-efficiency multi-junction solar cells cannot capture this entire spectral range," Lumb said in a statement. "Our new device is able to unlock the energy stored in the long-wavelength photons, which are lost in conventional solar cells."

PHOTO: ISTOCK, PREVIOUS PAGE: PROPEL

piece of mind

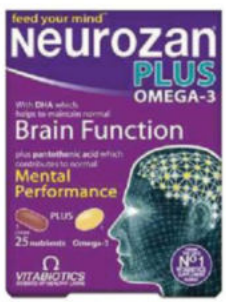
Neurozan®



Neurozan® is a comprehensive supplement with over **25 nutrients** and amino acids to support your daily intake. Including **pantothenic acid** which contributes to normal **mental performance**.

Also available is Neurozan® Plus, which includes the original tablet, plus an Omega-3 capsule containing **DHA** which contributes to normal **brain function**†.

Original



Plus Omega-3

Britain's No.1 Vitamin Company*

*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 18th June 2016.

From Boots, Holland & Barrett, Tesco, Waitrose, independent pharmacies & health stores, **www.neurozan.com**

†A beneficial effect is obtained with a daily intake of 250mg DHA.

45 YEARS VITABIOTICS Est. 1971

Britain's No.1 supplements*

The **ONLY** vitamin company to receive **The Queen's Award For Innovation**

VITABIOTICS
SCIENCE OF HEALTHY LIVING

ADNEUCONP 08-08-16E

BBC FOCUS

EDITORIAL
Editor Daniel Bennett
Production editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Online editor Alexander McNamara
Editorial assistant James Lloyd
Science consultant Robert Matthews
Contributing editors Emma Bayley, Russell Deeks

ART
Art editor Joe Eden
Designer Steve Boswell
Picture editor James Cutmore
Group art editor Susanne Frank

CONTRIBUTORS
Acute Graphics, Kat Arney, Peter Bentley, Susan Blackmore, Dan Bright, Jamie Carter, JV Chamary, Charlotte Corney, Helen Czerski, Emma Davies, David Despau, Alex Franklin-Cheung, Alice Gregory, Alastair Gunn, Stephen Hall, Ryan Inzanu, Christian Jarrett, Sarah Kennett, Kev Lochun, Raja Lockey, Mark Lorch, Magic Torch, Helen Pilcher, Aarathi Prasad, Dean Purnell, Helen Scales, Kyle Smart, Colin Stuart, Luis Villazon.

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Advertising manager Neil Lloyd
Senior brand sales executive Jonathan Horwood
Brand sales executive Anastasia Jones
Senior classified executive Jenna-Vie Harvey
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Derrick Andrews
Ad services manager Paul Thornton
Ad coordinator Jade O'Halloran
Ad designer James Croft

PUBLISHING
Content director Dave Musgrove
Commercial director Jemima Ransome
Publishing director Andy Healy
Managing director Andy Marshall

BBC WORLDWIDE
President of UK and ANZ Marcus Arthur
Director of editorial governance Nicholas Brett
Director for consumer products and publishing Andrew Moultrie
Publishing director Chris Kerwin
Publisher – magazines and NPD Mandy Thwaites
Publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcworldwide.com/uk-anz/ukpublishing.aspx

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £63; Europe & Eire Airmail £66;
Rest of World Airmail £70.

abc Audit Bureau of Circulations
58,368 (combined; Jan-Dec 2016)

IMMEDIATE MEDIA CO

BBC Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Worldwide who help fund new BBC programmes.

PHOTO: ALAMY

REPLY

Your opinions on science, technology and BBC Focus

reply@sciencefocus.com
BBC Focus, Tower House, Fairfax Street, Bristol, BS1 3BN
@sciencefocus
www.facebook.com/sciencefocus

MESSAGE OF THE MONTH

Natural inspiration

As someone who has worked in the operating theatre for 30+ years, I read your article on antibiotic resistance (Summer, p70) with great interest. I've seen a few new antibiotics appear over the years, and I've seen the devastating effects that multi-resistant organisms can inflict.

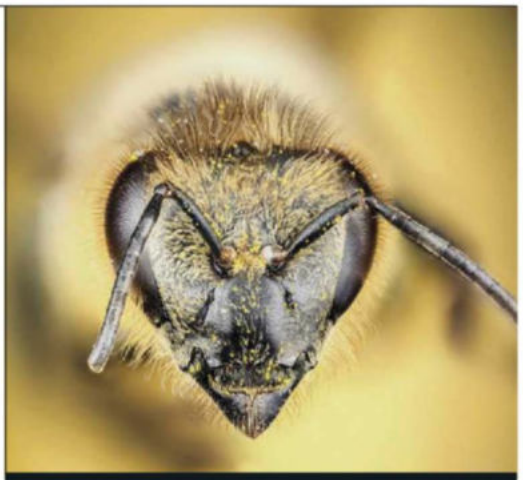
But something that your article didn't mention, probably because they would provide enough material for an article of their own, are alternatives to antibiotics.

Some long-term in-dwelling cannulae [thin tubes inserted into the body] are now silver-impregnated, as silver has natural antibacterial properties. As far as I am aware, no bacterium has yet developed resistance to them. Copper, too, has long been known to have similar qualities, and some companies are promoting the use of copper keyboards, pens and so on in the hospital environment, to help combat the spread of infection.

As well as these measures, nature provides us with a plethora of plants (echinacea, garlic, ginger, etc) that fight bacteria – and as a beekeeper, I have to mention that honey is a fantastic antibacterial wound dressing!

Maybe it's time that we left the penicillin on the shelf?

Mark Buckmaster, Leicester



Bees: with two mentions in 'Reply', they're buzzing right now

Busy bees

I beg to differ with Luis Villazon, who says "bees don't fly in particularly straight lines, either" (Summer, p80). A bee foraging for nectar and pollen will fly from flower to flower until they have a full load, but the fully laden bee will then fly back to the hive as straight as possible, in order to conserve energy – hence the saying 'making a beeline'. As children in Texas in the 1940s, we used to watch bees buzzing around flowers, and when we saw one fly off in a straight line we'd follow it back to the 'bee tree' where the honey was!

Samuel Walker, North Yorkshire

Facebooks

I was interested in your article on face recognition research done on rhesus monkeys (Summer, p16).

Having been a teacher for many years I always felt I remembered students' names in a similar way, effectively creating a mental database of facial features and associating a student's name with them. This worked well unless there were two students with a similar set of features, when I would call them by the wrong name and they would be deeply insulted. They didn't think they looked alike at all!

Nick Tupper, Hampshire

PC Specialist recommends Windows Windows 10

13.3" LAFITE III

- 13.3" Matte Full HD LED Screen
- Intel® Core™ i5-7200U
- 16GB Corsair 2133MHz
- INTEL® HD GRAPHICS 620
- 1TB SLIM SATA HDD (5,400)
- **Windows 10 Home**

This spec from **£799.00***

THE VULCAN-X-01

- OC Intel® Core™ i7-7820X
- ASUS® ROG STRIX X299-E
- 32GB Corsair VENGEANCE RGB 3000MHz
- 8GB EVGA GTX 1080 FTW2
- 1TB WD BLACK
- **Windows 10 Home**

This spec from **£2,249.00***

THE VELOCITY ZEN EXTREME

- AMD Ryzen 7 1800X
- ASUS® PRIME B350-PLUS
- 16GB Corsair VENGEANCE 2133MHz
- 8GB GEFORCE GTX 1080
- 240GB KINGSTON V300 SSD
- 1TB 3.5" SATA-III 6GB/s
- **Windows 10 Home**

This spec from **£1,549.99***

15.6" OCTANE III K15-1060

- 15.6" Matte Full HD IPS Screen
- Intel® Core™ i5-7600
- 8GB Kingston DDR4 2133MHz
- 6GB GeForce GTX 1060
- 1TB WD BLACK WD10JPLX
- 128GB M.2 2280 SSD 6Gb/s
- **Windows 10 Home**

This spec from **£1,389.99***

ENIGMA GT IV

- Intel® Core™ i3-7300
- ASUS® H110M-R
- 8GB Corsair VENGEANCE 2133MHz
- Integrated Graphics (HD)
- 1TB 3.5" SATA-III 6GB/s
- **Windows 10 Home**

This spec from **£479.99***

APOLLO K VR

- Intel® Core™i7-7700k
- ASUS® ROG STRIX Z270E GAMING - Wi-Fi
- 16GB Corsair VENGEANCE 2133MHz
- 8GB GEFORCE GTX 1080
- 250GB Samsung 850 EVO
- **Windows 10 Home**

COMPUTER SHOPPER RECOMMENDED

This spec from **£1,579.00***

0333 011 7000

/PCSPECIALIST @PCSPECIALIST

Some features require Windows 10. Update available through Windows Store. Internet access required; fees may apply.
Microsoft, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

* Prices are including VAT and are correct at the time of printing, but subject to change.

pcspecialist

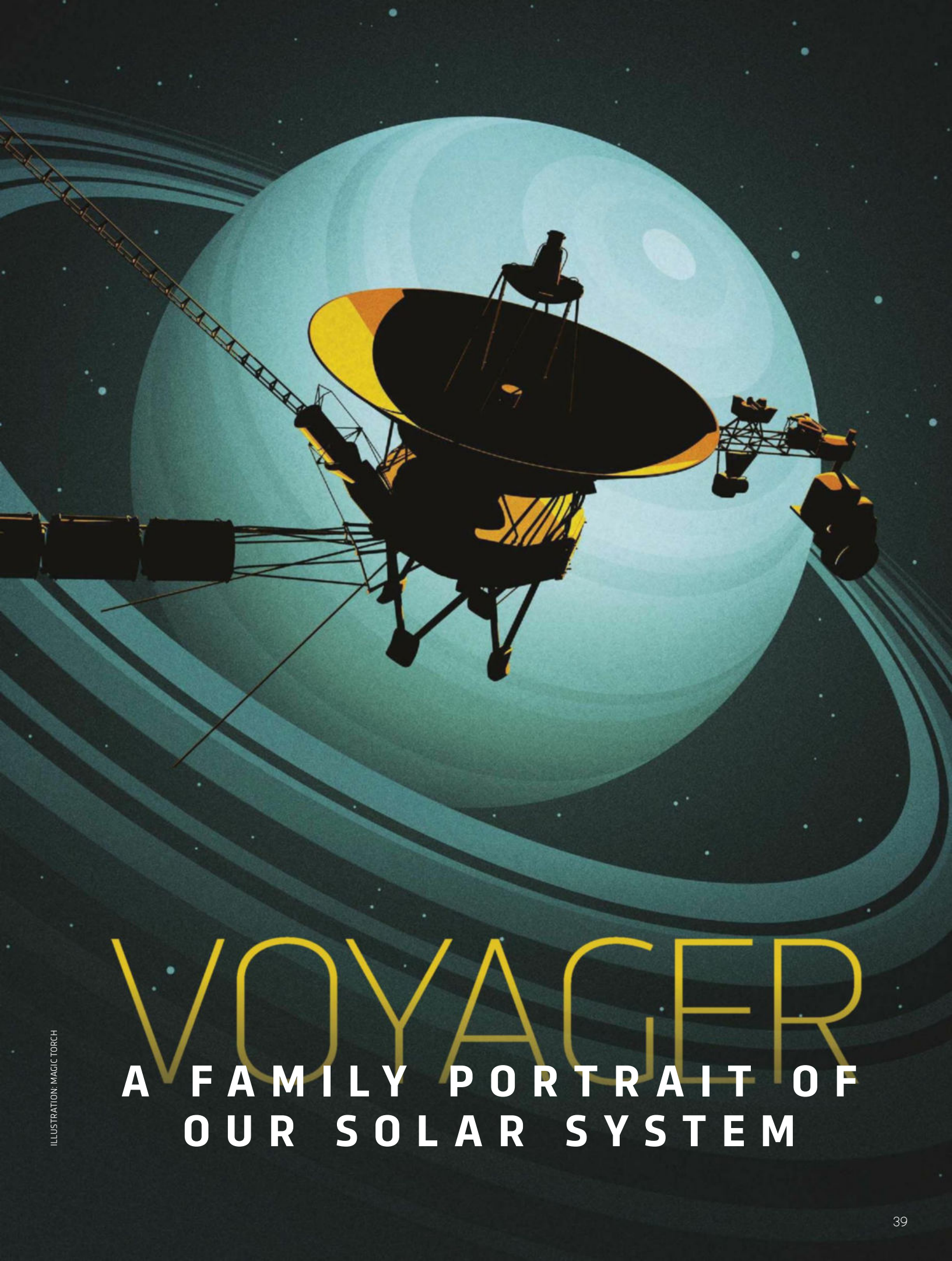
CUSTOM GAMING DESKTOPS & LAPTOPS

WWW.PCSPECIALIST.CO.UK

GET A FURTHER £15 OFF WITH THIS EXCLUSIVE VOUCHER CODE:

BBF57

ORDER ONLINE NOW AT WWW.PCSPECIALIST.CO.UK



VOYAGER

A FAMILY PORTRAIT OF OUR SOLAR SYSTEM

ILLUSTRATION: MAGICTORCH

IT'S 40 YEARS SINCE THE TWO VOYAGER CRAFT SET OFF ON THEIR QUEST TO EXPLORE THE OUTER SOLAR SYSTEM. THIS IS THE STORY OF THEIR JOURNEY...

Words: **Kev Lochun**

The day was 14 February 1990, and Voyager 1's camera, which had been inactive for 10 years, was turned on one last time. Then 5.95 billion kilometres from Earth, the spacecraft took 60 photos, which scientists at NASA's Jet Propulsion Laboratory (JPL) in California used to create the most distant portrait of the Solar System we have, a valentine to our planetary neighbourhood. Amid the darkness is Earth itself. It's not the gleaming Blue Marble of the Apollo era, but a Pale Blue Dot, a minuscule speck of dust (see opposite page). Right there, in a fraction of a pixel, is the stage for all human existence.

These sobering frames were the last to be photographed by either of the twin Voyager spacecraft, which started their journeys to the outer Solar System 40 years ago. They launched separately in the late summer and early autumn of 1977, from an Earth as unrecognisable today as the fragile dust mote seen by Voyager 1 in 1990. Jimmy Carter was in the White House and Donna Summer was singing about feeling love. A little-known movie called *Star Wars* was confounding all box office expectations. Pluto was still considered a major planet, and the idea that there might be other planets around other stars was but a theory.

The Voyagers would go on to confound expectations, too. Between them they completed a tour of Jupiter, Saturn, Uranus and Neptune, and in doing so transformed our knowledge of the Solar System. In a series of flybys, they showed us that the Galilean moons of Jupiter were not dead, airless rocks like ours, but distinct worlds with their own characters and mysteries. They revealed that the oft-mythologised rings of Saturn were varied and complex, riddled with spokes and weaves. They gave us our first close-up images of aquamarine Uranus and cobalt Neptune, seen previously only as fuzzy, indistinct blobs through telescopes on Earth. Between them they took pictures of 52 bodies, 23 of which were moons that had defied discovery until the Voyagers came along. Even now, with the planets of the Solar System long behind them, they continue to send back data as they push into interstellar space, the void between the stars.

THE SLINGSHOT EFFECT

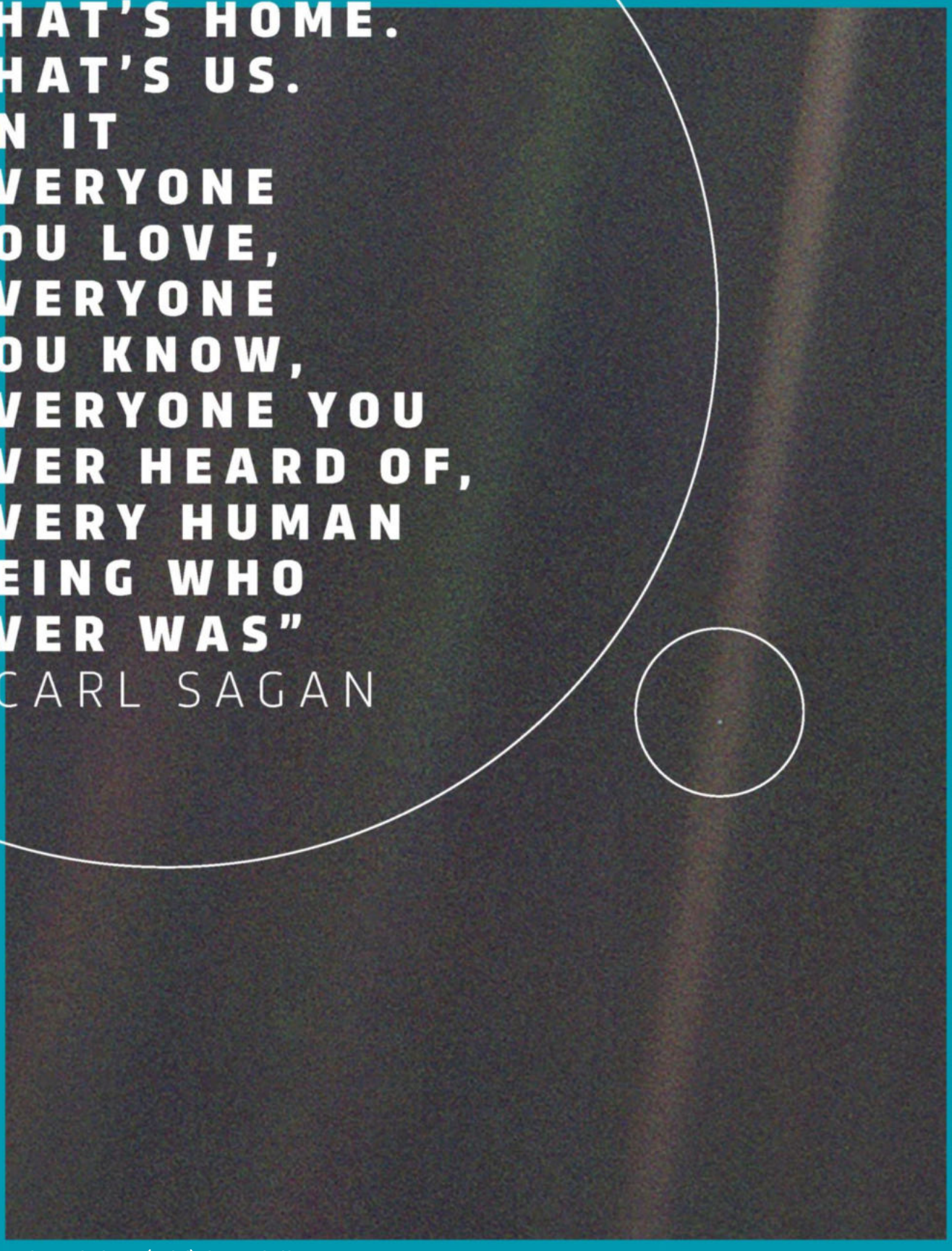
It was in May 1961 that US president John F Kennedy delivered his 'Moon shot' speech to Congress, in which he called on his country to put a man on the Moon before the decade was out. In the same speech, he talked about developing a nuclear rocket that would someday allow for even more ambitious missions, "perhaps to the very end of the Solar System itself".

At the time, the idea of sending any kind of craft such a long way was inconceivable. Using conventional rocketry, it would take 30 years to reach Neptune, far beyond the lifespan of any feasible spacecraft. The prevailing view was that the outer Solar System would remain out of reach until some form of 'high-energy' propulsion had been developed. That it didn't stay unobtainable ▶

September 1962: JFK gave his famous 'Moon speech' at Rice University, to encourage support of space exploration

PHOTOS: GETTY, NASA

"THAT'S HERE.
THAT'S HOME.
THAT'S US.
ON IT
EVERYONE
YOU LOVE,
EVERYONE
YOU KNOW,
EVERYONE YOU
EVER HEARD OF,
EVERY HUMAN
BEING WHO
EVER WAS"
– CARL SAGAN



Earth as a Pale Blue Dot (circled), photographed by Voyager 1 in 1990

"AT LAUNCH, URANUS AND NEPTUNE REMAINED OFF LIMITS. IT WAS ONLY AFTER THE SATURN ENCOUNTER IN 1981 THAT THE EXTENSION WAS GREENLIT"

Saturn with two of its moons, Tethys and Dione, as photographed by Voyager 1

was largely down to the work of two JPL interns, Michael Minovitch and Gary Flandro.

In 1962, Minovitch cracked a conundrum of classical mechanics: the three-body problem. This describes how the gravitational influence of two bodies affects the trajectory of a third. Typically, the first two bodies are the Sun and a planet, the third is a moon, comet or asteroid. The idea that a gravitational Goliath could alter the trajectory of a smaller entity was not a new one; astronomers of years gone by had witnessed the paths of comets being bent by Jupiter time and again. The 'problem' was being able to predict exactly how the third body's trajectory would be altered.

Minovitch not only solved it, but showed that this effect could be harnessed to send a spacecraft zipping across the Solar System without expending any more fuel than needed to launch it in the first place. All the probe had to do was pass sufficiently close to a planet orbiting the Sun in the same direction, and it would 'steal' some of the planet's momentum. The probe would be catapulted onwards at greater speed and in a new direction, while the planet would suffer almost imperceptible loss of inertia. The long-theorised idea of gravity-assisted travel was finally realised.

Fast-forward three years to 1965 and Flandro notices that Jupiter, Saturn, Uranus and Neptune will all be on the same side of the Solar System in the late 1970s and early 1980s, an alignment so rare it only comes about once every 176 years. During this period, a single spacecraft using gravity assists could visit them all, and it would only take nine years to reach Neptune. The day after

PHOTOS: NASA X10

VOYAGER'S GREATEST HITS

20 AUG 1977

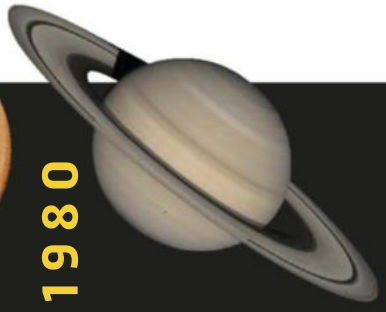
Voyager 2 launches from Cape Canaveral in Florida, on a longer and slower trajectory than its counterpart. Voyager 1 lifts off a couple of weeks later on 5 September, overtaking Voyager 2 in the asteroid belt.

5 MAR 1979

Voyager 1 makes its closest pass of Jupiter; Voyager 2 makes its flyby on 9 July. Together, they reveal new moons, rings and the gargantuan extent of the Jovian magnetosphere.

11 NOV 1980

Voyager 1 takes a close look at Saturn's moon Titan, discovering that it's not as large as expected. The crown of largest moon in the Solar System passes to Jupiter's Ganymede.



12 NOV 1980

Voyager 1 sails past Saturn, with Voyager 2 following on 25 August 1981. They confirm that the planet's famous rings are neither solid nor liquid, but thin aggregations of water-ice fragments.

Flandro presented his findings, JPL issued a press release describing a mission to the outer planets. The idea of the Grand Tour was born.

JPL's early ambitions matched the rarity of the occasion: four spacecraft, plus orbiters and atmospheric probes, with a colossal price tag of $900m. That proved too steep for Congress, and in 1971 the Grand Tour was abandoned. From its ashes came Voyager, a stripped-back mission ostensibly limited to Jupiter and Saturn, but NASA's engineers never gave up on the idea of the tour. Two trajectories were chosen out of 10,000: Voyager 1 would fly past Jupiter, Saturn and its large moon Titan, but Voyager 2's course left open a mission extension to Uranus and Neptune. They were built with these distant worlds in mind – batteries that could last for decades, enough fuel to keep the probes' antennas aimed at Earth and, for the first time, programming that allowed the spacecraft to fly themselves.

At launch, Uranus and Neptune remained off limits. It was only after the final Saturn encounter in 1981, following a parade of discoveries and data, that the extension was greenlit. Only then was JPL's optimism rewarded.

A WHOLE NEW WORLD

When the Voyagers reached Jupiter in 1979 – Voyager 1 making its closest pass in March, Voyager 2 in July – they set a precedent for rewriting the textbooks, a feat repeated during every flyby thereafter.

One of the biggest surprises was Jupiter's moon Io. It was not the grey and barren rock that scientists expected it to be, but a blotchy kaleidoscope of oranges, yellows and bluish-whites, scarred by erupting volcanoes and lava flows. It was the first time that active volcanism had been observed anywhere beyond Earth. A set of rings was also discovered around Jupiter itself; not majestic like Saturn's, but thin and dusty. And for the first time, the Great Red Spot was seen close-up, revealing it to be a massive, anticyclonic storm system large enough to swallow three Earths. Here – and during every following encounter – the Voyagers refined our estimates of the planet's size, the length of its day, the nature of its magnetosphere and its internal composition.

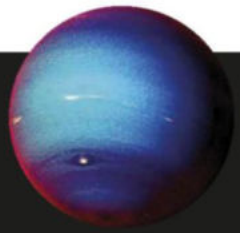
At Saturn, the probes provided the visual proof that the planet's rings, seemingly solid through even modern telescopes, were conglomerations of water-ice chunks ranging from less than 1cm in size to more than 10m. More surprising was their complexity. Each of the nominally individual A, B and C rings were found to be comprised of dozens of smaller ringlets. The 'Cassini Division', the empty gap between the A and B rings, was not empty at all but littered with fragments of dust and rock. Two more rings were found, as were the first 'shepherd moons' – Prometheus and Pandora – situated on either side of the planet's outer F ring. Shepherd moons are bodies within the ring plane that contain, corral and shape the rings themselves. A third shepherd moon, the walnut-shaped Pan, was spotted years later in images from Voyager 2.

But it was the featureless orange blob of Titan that mission scientists were most excited to see, the only moon in the Solar System known to have a substantive atmosphere – so thick that Voyager 1 was unable to see the moon's surface. What the probe did determine was that the haze was dominated not by water, but by methane and other organic compounds, spawning theories that Titan could be an analogue to conditions on a much younger Earth. Radio experiments also revealed that Titan was not the largest moon in the Solar System as had been long believed: its enormous atmosphere made it appear bulkier than it really was.

From here the Voyagers went their separate ways. As Voyager 1 careered away from the plane of the planets, Voyager 2 sped on to Uranus for a January 1986 flyby. This planet proved to be somewhat serene, lacking the distinct storms and latitudinal banding seen on Jupiter and Saturn. It was quite different internally, too: its ▶

24 JAN 1986

First encounter with Uranus. Voyager 2 discovers a bland planet with an unusual composition, leading to a new classification: ice giant.



25 AUG 1989

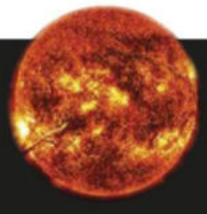
Voyager 2 becomes the first probe to visit Neptune, which also turns out to be an ice giant. The spacecraft discovers that Neptune has partial rings and the strongest winds in the Solar System.

14 FEB 1990

Voyager 1's camera is turned on one last time to take a family portrait of our Solar System. Among the images is the now iconic Pale Blue Dot.

17 FEB 1998

Voyager 1 overtakes Pioneer 10 to become the most distant human-made object in space, 10.4 billion kilometres from Earth.

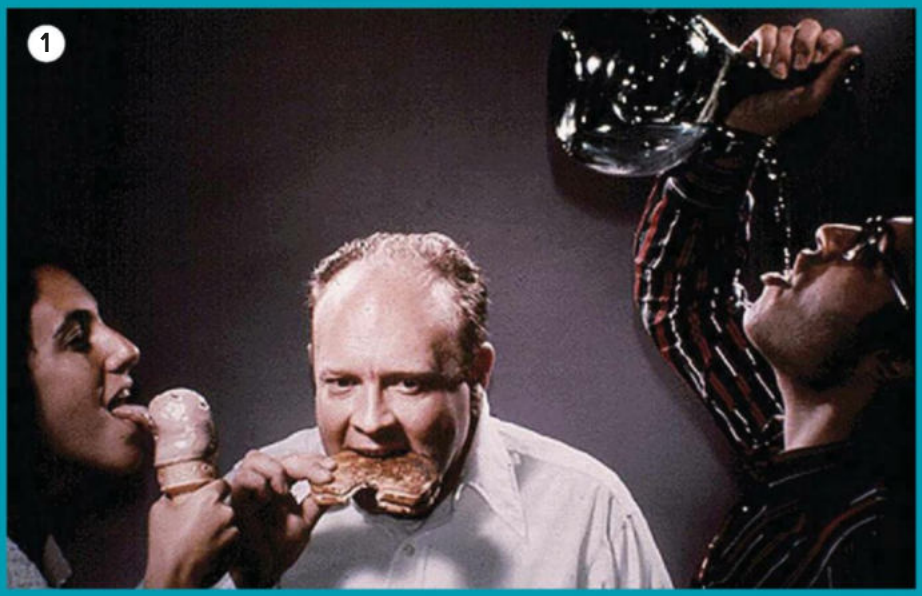


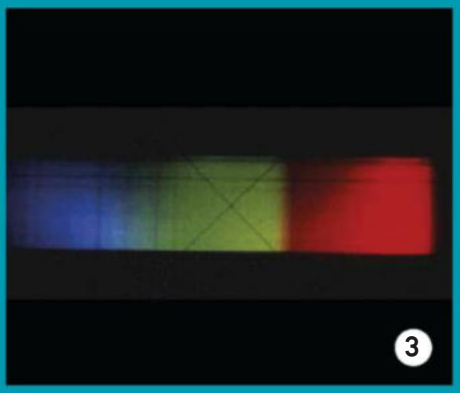
25 AUG 2012

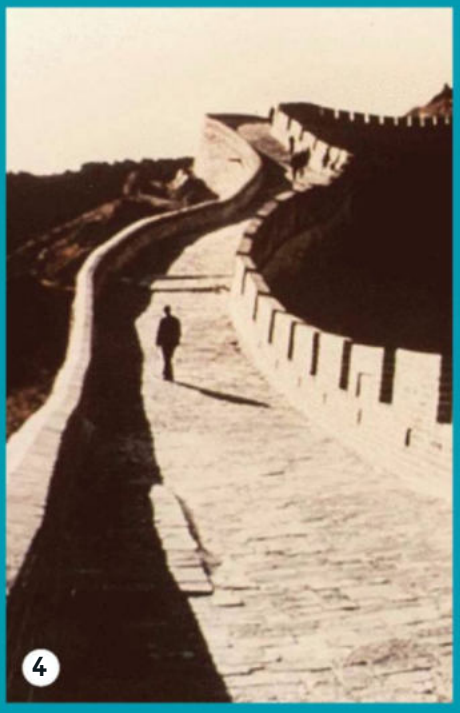
Voyager 1 becomes the first craft to enter interstellar space. NASA is only able to determine this 13 months later, after a coronal mass ejection from the Sun catches up with it.

MESSAGES TO ET

Bolted to the underside of each of the Voyager probes is a 12-inch gold-plated copper disc, the Golden Record. It's a time capsule of Earth as it was in 1977, laden with images, music and diagrams: a message for any alien civilisation that might chance across it. The contents offer a snapshot of human life and our place in the Universe. Among its 116 images (five of which are shown here) are depictions of human anatomy, plants and animals, landscapes and scenes of everyday life. There are audio greetings in 55 languages, some 'Earth sounds' and 90 minutes of music, including works by Beethoven, Mozart and Bach, a Navajo chant, a Peruvian wedding song and Chuck Berry's *Johnny B. Goode*. It also carries a recording of the brainwaves of Voyager team member Ann Druyan, in the hope that another race might be able to decipher them.







1 Eat up!
This unusual image demonstrates how we lick, eat and drink. You drink like this too, right?

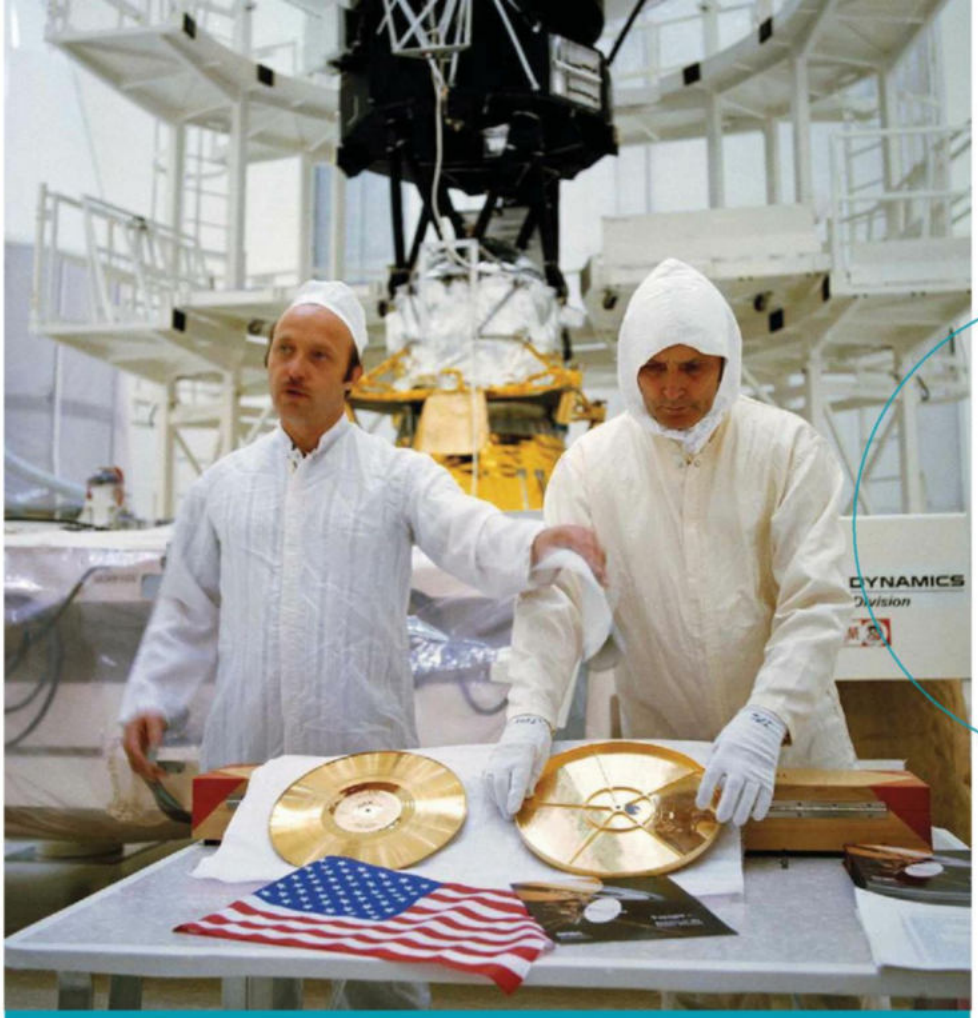
2 Wonderful wildlife
Pictures of our planet's animals include dolphins, an eagle, a crocodile, an elephant, and this cute toad.

3 Solar spectrum
The disc features the Sun's spectrum of light in visible colours, perhaps to help aliens identify the Sun.

4 Engineering marvel
The Great Wall of China is one of our most famous structures. Despite rumours, it is not visible from space.

5 Human athleticism
Sporting activities feature in several images – also included are photos of runners and a mountain climber.

PHOTOS: NASA X5, SCIENCE PHOTO LIBRARY, NATIONAL ASTRONOMY AND IONOSPHERE CENTER



The Golden Record was installed on each of the Voyager craft before launch

“THEY WILL DRIFT AMONG THE STARS, EDGING TOWARDS A DESTINATION OF WHICH JFK COULD ONLY DARE TO DREAM”

composition being dominated by ices of water, methane and ammonia, leading it to be given the new classification of ‘ice giant’. Voyager 2 photographed 11 rings around Uranus – two more than anticipated – but it was its moon Miranda that confounded, with its mix of young and old surfaces and patchwork of icy cliffs, canyons and strange chevrons. It looks like Miranda has been pulled apart and forced back together more than once throughout its life.

Neptune was also revealed to be an ice giant, but it was not as calm as Uranus. Voyager 2’s flyby in August 1989 revealed a number of storms, including an Earth-sized anticyclone that became known as the Great Dark Spot, and the most ferocious winds in the Solar System. It amazed the mission team that a world so cold and so far from the Sun could be so atmospherically active.

As if to bookend the Voyagers’ planetary explorations, the last moon either spacecraft visited proved to be as exciting as Io. Frosty Triton was found to have a gigantic seasonal polar cap and active geysers spewing nitrogen into a thin atmosphere. Most exciting were the revelations that Triton orbits Neptune backwards in relation to the planet’s other moons, suggesting that it may be an object from the icy outskirts of the Solar System (the Kuiper Belt) that became trapped in Neptune’s orbit.

INTO THE VOID

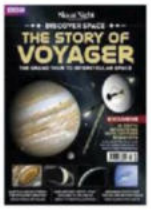
Voyager 1’s family portrait of the Solar System in 1990 marked the end of the Grand Tour and the beginning of the Voyager Interstellar Mission, a new phase to explore the bounds of our Sun’s influence in space, in a bubble called the heliosphere.

In 2004 it reached the termination shock, the region where the solar wind, the breeze of particles streaming from our Sun, begins to quieten. It wasn’t until 2012 that Voyager 1 detected the change in high-energy particles that confirmed it had crossed the heliopause – the ‘boundary’ – and entered interstellar space. So far it is the only spacecraft to do so; Voyager 2 is expected to follow within five years. Yet it still can’t be said that Voyager 1 has left the Solar System. That will happen when it passes through the Oort Cloud, the hypothesised shell of icy bodies that surrounds us. Depending on which estimate you use, that could take another 40,000 years.

By that time, both of the Voyagers will have fallen quiet. Even today they might be considered senior citizens. A number of instruments have failed, while several more have been permanently disabled to lessen the power drain on their batteries. The craft are expected to keep transmitting data until 2025, but beyond that, when their weak signals finally disappear, they will drift silently among the stars, edging towards a destination of which JFK could only dare to dream.

Kev Lochun is a science and history journalist. He tweets from @kevlochun

DISCOVER MORE



For more on the mission’s history and discoveries, check out *The Story Of Voyager* from the makers of *BBC Sky at Night Magazine* (£11.49, available now). Call **03330 162 138** or visit **buysubscriptions.com/voyager**

BBC FOCUS

FOP312

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST IMMEDIATE MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Focus* and pay £17.95 every six issues – saving 40% **(please complete form below)***

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____

Surname _____

Address _____

_____

_____ Postcode _____

Home phone no _____

Mobile phone no _____

Email _____

☐ **I wish to purchase a gift subscription**
(please supply gift recipient's name and address on a separate sheet)

Instructions to your bank or building society to pay by Direct Debit

DIRECT Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number | **Branch sort code**

Reference number (internal use only)

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature | Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

Your personal information will be used as set out in our privacy policy, which can be viewed online at **immediate.co.uk/privacy-policy. Immediate Media Company Limited would love to send you newsletters, together with special offers, and other promotions. Please tick here if you'd prefer not to receive these by email ☐ text message ☐ regular post ☐ telephone ☐

Branded BBC titles are licensed from or published jointly with BBC Worldwide (the commercial arm of the BBC). Please tick here ☐ if you'd like to receive regular newsletters, special offers and promotions from BBC Worldwide by email. Your information will be handled in accordance with the BBC Worldwide privacy policy which can be viewed online at **bbcworldwide.com/privacy.aspx**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £52.40 for 14 issues, **saving 25%**

☐ **Europe** inc Eire – £73.35 for 14 issues

☐ **Rest of world** – £74.75 for 14 issues

☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to:
BBC Focus Magazine, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 13 October 2017.** 40% saving is only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue.

You may photocopy this form

SPECIAL SUBSCRIPTION OFFER

SAVE 40% ON THE SHOP PRICE!

SPREAD THE COST AND PAY JUST **£17.95 EVERY 6 ISSUES** BY DIRECT DEBIT!*

RECEIVE EVERY ISSUE DELIVERED DIRECT TO YOUR DOOR WITH **FREE UK DELIVERY**

HURRY! OFFER ENDS 13 OCTOBER 2017

NORMALLY ~~£4.99~~
YOU PAY
£2.99


KEEP IN TOUCH WITH THE FUTURE
SAVE 40%
SUBSCRIBE TODAY
PLEASE QUOTE FOP312*
ONLINE
www.buysubscriptions.com/FOP312
BY PHONE
03330 162 113+
BY POST
FREEPOST IMMEDIATE MEDIA
(please write in capitals)
+ Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-6pm weekdays and 9am-1pm Saturday for orders only. If calling from overseas, please call +44 1604 973 721

VOYAGER: BEYOND OUR SOLAR SYSTEM

In August 2012, NASA's Voyager 1 probe became the first human-made object to enter interstellar space – the vast area that lies between the many star systems in our Galaxy. Once thought to be empty, it now seems the interstellar medium could be the key to understanding dark matter, the birth of stars and the origin of life

WORDS: COLIN STUART

ILLUSTRATION: MAGIC TORCH

FORMATION OF STARS AND GALAXIES

By studying what matter there is in the interstellar medium, scientists hope to learn more about how stars are born

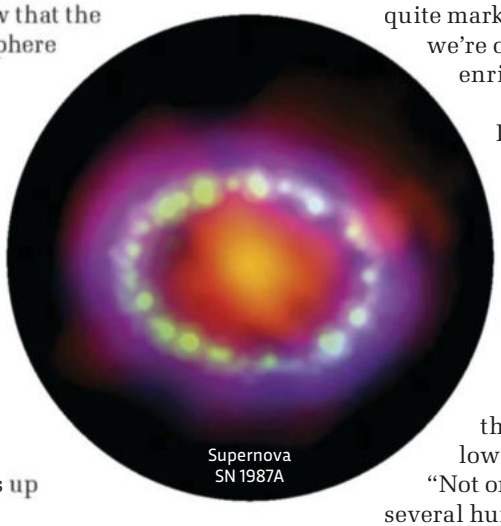
Space is called 'space' for a reason. The gaps between the stars are incredibly empty – far more sparsely populated than any vacuum we can create here on Earth.

Astronomers call this area the interstellar medium (ISM). And though it may be diffuse, it's thought to make up at least 10 per cent of the visible mass of our Galaxy. Stars sit embedded in the ISM, but are not isolated from it.

"Stars are born inside the interstellar medium," says Mikako Matsuura from the University of Cardiff. "It's like an ecosystem."

The Voyagers have been able to study the birth of stars by recording the distinctive patterns of ultraviolet light that are associated with star formation, which are known as Lyman alpha emissions. We haven't been able to see this radiation in our own Galaxy up till now, because the Sun's emissions cloud them out. But now that the Voyagers are on the edge of heliosphere – the area where the influence of Solar wind is stopped by the ISM – they have been able to detect it, helping us map out previously unobserved regions of star formation in the Milky Way.

Throughout their lives, stars turn lighter elements into heavier ones through the process of nuclear fusion. Then when stars die, they send those heavy elements back out into the interstellar medium. This exchange of material ultimately governs how quickly a galaxy uses up its supply of gas.



Supernova SN 1987A

Exploring this eternal feedback loop allows us to learn more about stellar evolution. The death of massive stars enriches galaxies with elements such as carbon, oxygen and iron, which changes the abundance of those elements over time.

"As the enrichment proceeds, the fraction of stars ejecting carbon-rich molecules and dust particles decreases," says Patrick Roche, from the University of Oxford. Given that we're a carbon-based life form, this means that the material suitable for living things like us is gradually decreasing.

Voyager 2 has been instrumental in the study of supernovae – huge stars that explode upon reaching the end of their lives. When the supernova SN1987A exploded in the Tarantula Nebula around 163,000 light-years from Earth in 1987, Voyager 2 was quickly swivelled round for a closer look. Since then, further observations have shown that the area continues to evolve.

"Not only has the ejected material expanded and cooled, the mass of dust and molecules has grown quite markedly," says Roche. In other words, we're observing the process of enrichment in action.

Studying how stars form out of the ISM also tells us something about how common our Sun and Solar System are, compared to other solar systems in the Universe. And it turns out ours is actually quite unusual. "Our view of the balance between high mass stars and low mass stars has shifted," says Roche.

The latest observations suggest that the ISM is filled with a lot more low mass objects than we'd realised. "Not only is our Galaxy teeming with several hundred billion stars," says Roche, "There are almost as many brown dwarfs [an object larger than a planet but smaller than a star] and planetary mass objects out there, too."

With the two Voyager probes rapidly approaching the end of their lives, Matsuura and Roche have both turned to the new Atacama Large Millimeter Array (ALMA) – a bank of 66 radio dishes spread out in the bone-dry Chilean desert.

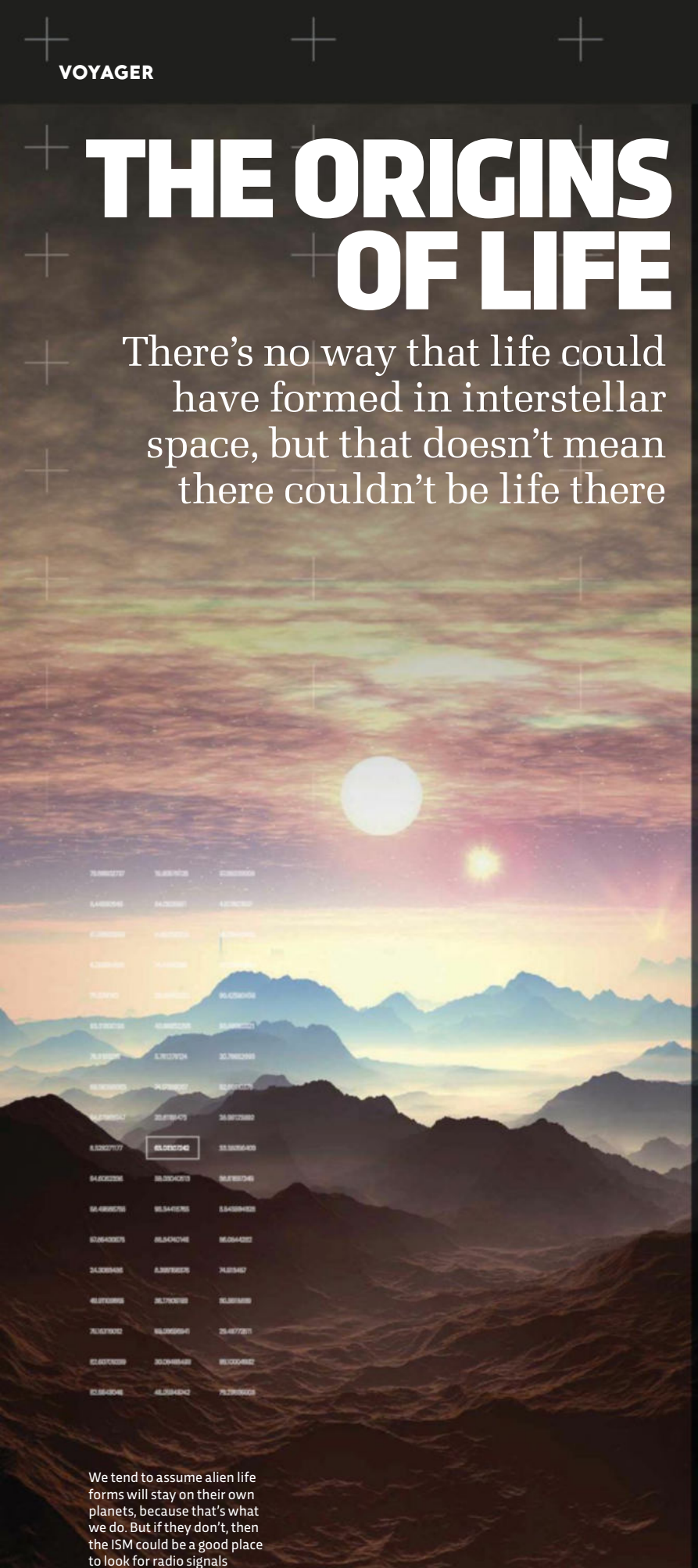
"ALMA really makes a difference," says Roche. "For the first time, we have the sensitivity to look at the ISM in detail."

PHOTOS: NASA, ALAMY

The Atacama Large Millimeter Array in Chile began scientific studies in 2011, and is enabling astronomers to study the interstellar medium in unprecedented detail

THE ORIGINS OF LIFE

There's no way that life could have formed in interstellar space, but that doesn't mean there couldn't be life there



We tend to assume alien life forms will stay on their own planets, because that's what we do. But if they don't, then the ISM could be a good place to look for radio signals

Could life on Earth have originated in interstellar space? "No, not a chance," says Lewis Dartnell, an astrobiologist at the University of Westminster. But that doesn't stop the ISM being an important area of study. "There's a lot of interesting astrochemistry going on," says Dartnell.

Amino acids – the building blocks of DNA – have already been found in meteorites from asteroids that pre-date the formation of the Earth. "But that's just the Lego bricks of life. There's nothing anywhere near as complex as a fully formed cell," Dartnell says.

Life couldn't have got started under those conditions without water or energy. "It's like throwing a bunch of chopped vegetables on the floor and expecting it to make soup," says Duncan Forgan, an astrobiologist from the University of St Andrews.

However, the fact that they seem so ubiquitous has a lot of astrobiologists excited about the chances of finding biology elsewhere in the Universe. If those ingredients end up on a warm world with water, then the necessary chemistry might be able to occur.

"My impression is that all this actually tells you is that carbon as an element is just really good at chemistry and building up complex molecules," Dartnell says. "If the cold vacuum of interstellar space is making amino acids, you can bet your bottom dollar that same chemistry is going on in the warm oceans of a new world."

If life can't form in the ISM, what are the chances of it starting out on a planet, then escaping that world and travelling across interstellar space to seed another? On this idea – panspermia – Dartnell is equally sceptical. "The idea has really fallen out of favour," he says. "The numbers just don't add up."

However, interstellar space could be the place to listen for signals from alien civilisations. So far we've focused on star systems because we're largely confined to our own world. But alien life may not be restricted in the same way.

"Those signals might come from interstellar space as well, if alien civilisations have spread beyond their home world and are voyaging between the stars," says Dartnell.

Interactions between the Sun and the ISM may also play an important role in shielding us from radiation from the wider Galaxy, in much the same way the Earth's magnetism acts as a force field to keep out dangerous radiation from the Sun.

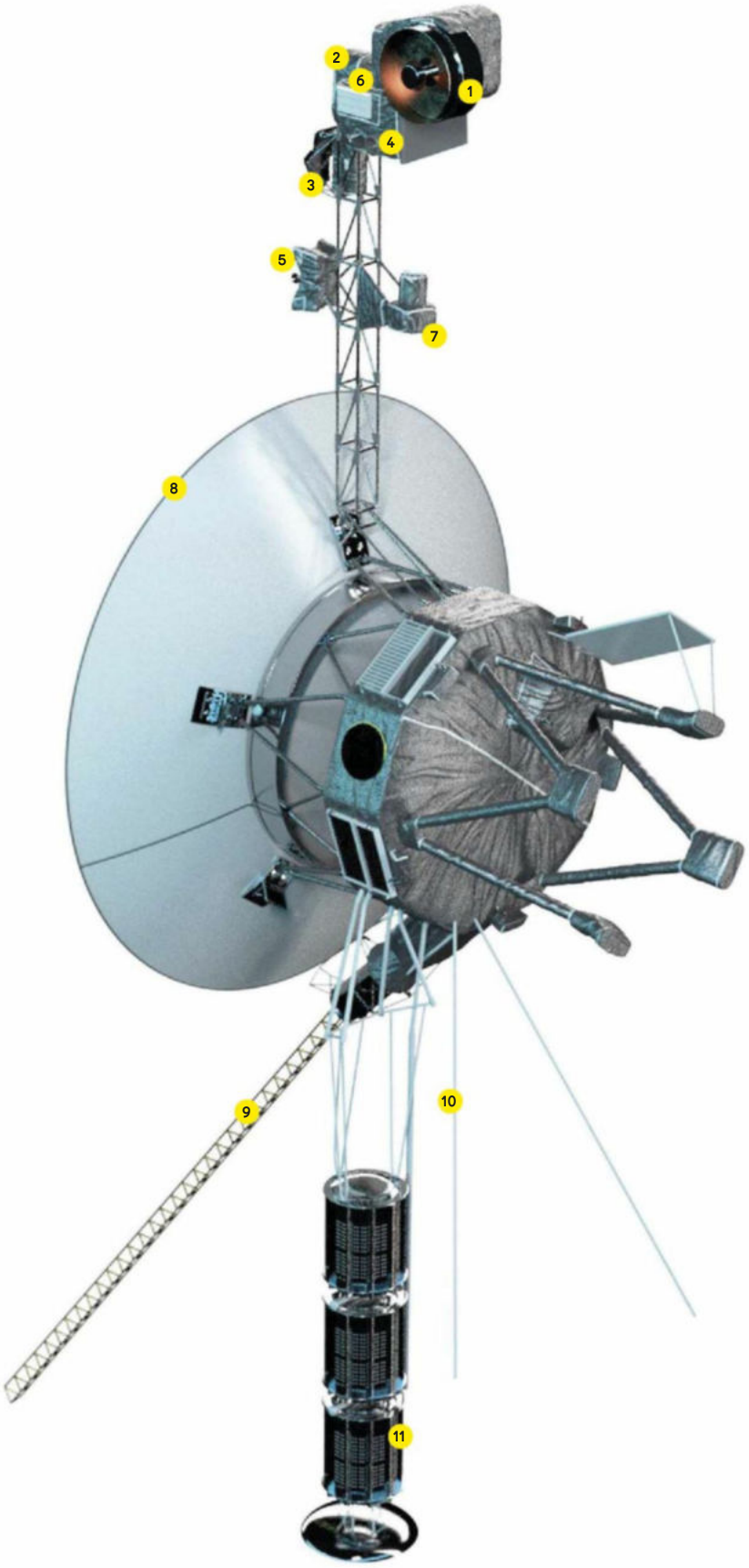
"It might be the case that having two magnetic fields protecting us is better than one," says Forgan.

The Voyager probes, at the boundary between the Sun's magnetosphere and deep interstellar space, are uniquely placed to make measurements of this region.

Now that it is out of the heliosphere, Voyager 1 has noticed a significant spike in the number of cosmic rays. By comparing this to the radiation levels from when it was inside, we can learn to what extent we're protected by the heliosphere. That data will help astronomers and astrobiologists figure out to what extent the double shield idea is true, and whether that has a knock-on effect for our notions about how common life might be around other stars.

THE VOYAGER PROBES

A closer look at the instruments onboard



1. INFRARED INTERFEROMETER SPECTROMETER AND RADIOMETER (IRIS)
Used to measure the brightness, temperature and chemical composition of the planets. Worked across ultraviolet, visible and infrared frequencies
● **Status: Off** (both spacecraft)

2. IMAGING SCIENCE SUBSYSTEM
The probes' eyes. Two television cameras, each with eight filters, mounted in a wheel that rotates in front of the lens.
● **Status: Off** (both spacecraft)

3. PLASMA SUBSYSTEM (PLS)
As its name suggests, this looks for slow-moving particles in plasma – a charged gas that has seen electrons stripped from atoms.
● **Status: Off** (Voyager 1)
● **Status: On** (Voyager 2)

4. ULTRAVIOLET SPECTROMETER
This was used for studying planetary atmospheres.
● **Status: Off (both spacecraft)**

5. COSMIC RAY SUBSYSTEM (CRS)
The CRS looked for high energy particles being accelerated in the magnetic fields of the giant planets. Now it can detect cosmic rays.
● **Status: On** (both spacecraft)

6. PHOTOPOLARIMETER (PPS)
A 20cm-aperture telescope capable of measuring the polarisation of light.
● **Status: Off** (both spacecraft)

7. LOW ENERGY CHARGED PARTICLE (LECP)
One of the three particle sensors on board, it can detect particles with a broader range of energies than CRS or PLS.
● **Status: On** (both spacecraft)

8. HIGH GAIN ANTENNA
This is how Voyager sends daily communication back to Earth. Signals were originally sent over two bands, but one band was shut off once the probes left the planets behind.
● **Status: On** (both spacecraft)

9. MAGNETOMETER
Originally measured the magnetic field of the planets. Now it is measuring changes in the Sun's magnetic field at the boundary with interstellar space.
● **Status: On** (both spacecraft)

10. PLANETARY RADIO ASTRONOMY (PRA) and PLASMA WAVE ANTENNA (PWA)
Two radio antennas at right angles to each other. One is for low frequency radio waves, the other for high frequency.
● **Status: PRA Off** (both spacecraft)
● **Status: PWA On** (both spacecraft)

11. RADIOISOTOPE THERMOELECTRIC GENERATOR
This is the power source of the Voyager probes. After 2020, engineers will begin turning more of their instruments off to preserve power.
● **Status: On** (both spacecraft)

Radioactive emissions from celestial bodies such as the Bullet Cluster, also known as 1E 0657-56, may shed more light on the nature of dark matter

DARK MATTER

What can venturing beyond the Solar System tell us about this most elusive cosmic phenomenon?

It appears gas and dust aren't the only things existing between the stars. There isn't enough visible material to account for the gravity needed to hold the rapidly rotating Milky Way together, so it has been suggested there's some invisible material called dark matter that lurks all around us – including in interstellar space.

Astronomers initially thought that dark matter might just be ordinary stuff that was too dim to see – objects such as brown dwarfs, stray planets and solar-mass black holes. These came to be known as MACHOs (Massive Compact Halo Objects). However, they should be detectable by other means, and we haven't found enough of them yet.

Now, the leading modern idea is that dark matter is made of WIMPs (Weakly Interacting Massive Particles) – a new form of matter that doesn't fit with the Standard Model of particle physics. But so far, snaring a WIMP, or even proving their existence, has been out of reach. However, according to the University of Lancashire's Cristina Popescu, studying the ISM might well help.

The Milky Way is full of cosmic rays – high energy particles created by apocalyptic events such as supernova explosions. When these rays strike interstellar dust and gas, they create a flood of gamma rays. Yet there are more gamma rays in the Milky Way than astronomers expected, particularly near the centre of the Galaxy.

"You look at the spectrum of what's left over, and it matches what you'd expect from the annihilation of WIMPs," says Popescu. Annihilation is where two WIMPs collide to create gamma rays. "Of course, this all relies on a good understanding of the interstellar medium," she says.

Unfortunately, the Voyager probes were launched before the idea of WIMPs was dreamt up. However, annihilating WIMPs should produce particles that they could detect, at least in theory.

Some accounts of dark matter also invoke the presence of a so-called dark photon. Proposed in 2008, this hypothetical particle is supposed to carry the force of dark matter, much like an ordinary photon carries the electromagnetic force. In 2015, a team of French physicists at the Université Grenoble Alpes used data from the Voyager probes to look for the magnetic signature of dark photons in the ISM. While they didn't find it, they did put some constraints on its properties, so the net is narrowing.

Then, last year, a team of astronomers from Australia and the UK looked at the effect on galaxies of ultra-compact mini-halos of dark matter (UCMHs). These are particularly dense dark matter clumps. They calculated that if only 1 per cent of a galaxy's dark matter was in the form of UCMHs, the heat from dark matter annihilations would be enough to eject all of the gas out of the interstellar medium in the immediate vicinity. This would prevent stars forming within around 3,200 light-years of the mini-halo. So looking for such gaps in the ISM is another way to learn more about the distribution of dark matter.

Colin Stuart is an astronomy writer and co- author of *The Geek Guide To Life*. He tweets from @skyponderer

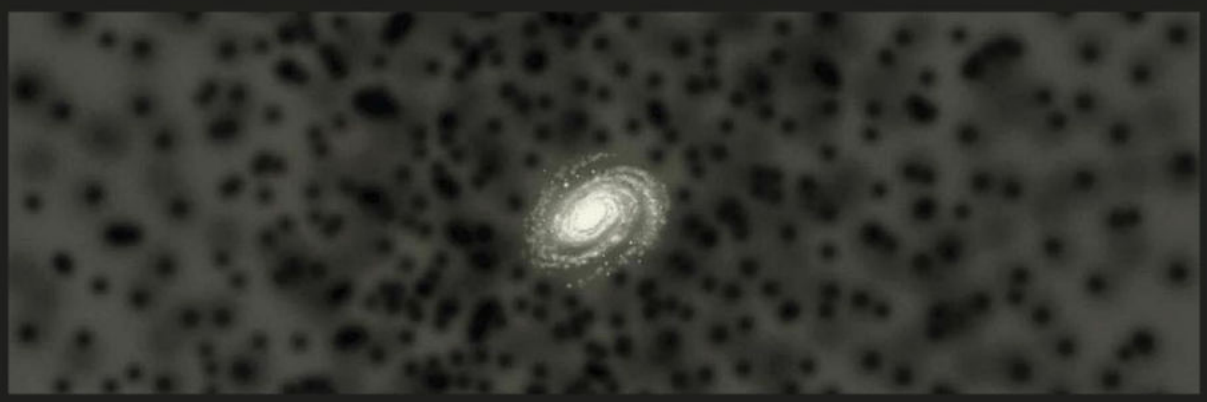
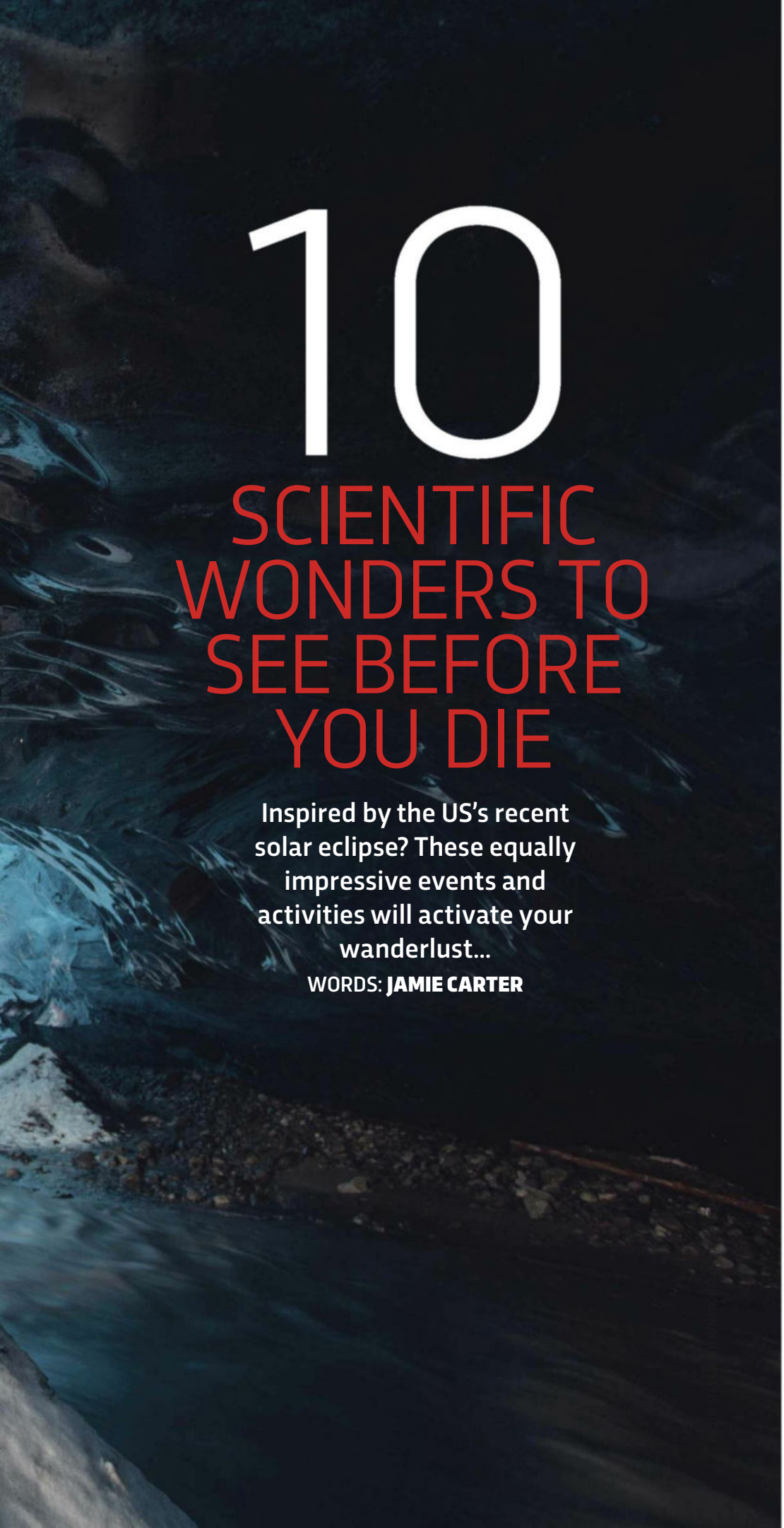


PHOTO: NASA, SCIENCE PHOTO LIBRARY



10 SCIENTIFIC WONDERS TO SEE BEFORE YOU DIE

Inspired by the US's recent solar eclipse? These equally impressive events and activities will activate your wanderlust...

WORDS: **JAMIE CARTER**

1. EXPLORE CRYSTAL CAVES INSIDE A GLACIER

Drive along Iceland's iconic Ring Road and you'll pass many enormous glaciers. Inside some of them are glorious ice caves with translucent walls that produce weird light in hundreds of shades of blue. It's a photographer's dream. "Most of them [the caves] are formed by water running either through tunnels in the ice, or on the ground underneath the glacier," says landscape photographer Iurie Belegurschi at Iceland Photo Tours, who takes groups into the ice caves within the vast Vatnajökull glacier in southeastern Iceland.

Although there are many ice caves in Iceland, Vatnajökull's are the most accessible. Safety is still important, though. "It's safe to visit ice caves from November to March when it's coldest outside and they're stable," says Belegurschi. "But always get a professional, local ice cave guide, who will provide you with all the safety gear and know exactly which caves are safe to enter."

Where to go: Southeastern Iceland
When to go: November-March
Cheapest flights: £75 (London-Reykavik)

2. PEER INTO HELL

As attractions go, the Darvaza Gas Crater in Turkmenistan's Karakum Desert is as strange as it is scorching. Back in 1971, Soviet geologists were searching the area for oil fields. Unbeknown to them, they had started their exploratory drilling on top of a cavern filled with natural gas. The ground collapsed, swallowing their equipment and opening up a huge crater. Fearing that toxic gases could harm local people, it was set on fire. This is called 'flaring', and is a familiar way of dealing with such a problem. But it backfired at Darvaza. Instead of burning for the expected two weeks, it's been blazing non-stop ever since it was ignited.

At around 60 x 20m, the largest crater is now a tourist attraction, which is referred to as the 'Gates to Hell'. It's best visited from Ashgabat, the country's capital, about 250km south. Take an organised tour, specifically one that visits the crater at night when it's at its most spectacular.

Where to go: Karakum Desert, Turkmenistan
When to go: Anytime
Cheapest flights: £540 (London-Ashgabat)

3. BEHOLD A NEVERENDING LIGHTNING STORM

Think lightning never strikes twice? The odds are more generous over the mouth of the Catatumbo River at Lake Maracaibo, Venezuela, which hosts lightning storms for up to 297 nights a year, thanks to some freakish topographical conditions.

Lake Maracaibo is a huge body of water surrounded by warm swamps, and encircled by the Andes. The intense solar radiation heats up the water, slowly saturating the atmosphere with water vapour. When cold winds push down from the Andes, they force this warm, moist air upwards, creating the perfect conditions for the development of dense, lightning-bearing cumulonimbus clouds.

"Watching the Catatumbo lightning is an experience you will get nowhere else," says Jonas Piontek, a German photographer who has travelled to Lake Maracaibo twice to capture the storms. "You are basically isolated from everyone: no network, no internet, no real civilisation around for a radius of at least 50km. It's just you and nature, and one of the best shows on Earth."

Where to go: Catatumbo Camp, Venezuela (**catatumbotour.com**)
When to go: October-November
Cheapest flights: £475 (London-Caracas)

PHOTOS: SHUTTERSTOCK, ALAMY, NATIONAL GEOGRAPHIC

4. WATCH A TOTAL SOLAR ECLIPSE

Don't worry if you couldn't make it out to the US this summer to witness the solar eclipse – they happen somewhere on Earth every 18 months. The spectacle is brief, but dramatic. "The sky suddenly darkens, and if you're watching with eclipse glasses you will see the crescent of the Sun rapidly shrink and break up into a series of beads," says eclipse cartographer Michael Zeiler. "Then you see a beautiful diamond ring around the Moon."

Moments later, the Sun's corona – its super-heated outer atmosphere – appears as an ice-white halo. To catch the next one, head out to Chile or Argentina for 2 July 2019.

Where to go: Chile
When to go: 2 July 2019
Cheapest flights: £450 (London-Santiago)

5. GAZE AT LIQUID FIRE

"So you're walking through a valley and all of a sudden a waterfall catches on fire," says photographer Dave Gordon. He is speaking about a phenomenon that takes place in Yosemite Valley's Horsetail Falls during late February, when light from the setting Sun causes the flowing water to glow yellow, orange and red, mimicking fire. "It occurs once a year, for a few days in a row, each lasting mere minutes," says Gordon. "So in total your chance of seeing a Yosemite waterfall turn into what looks like lava, or flowing fire, is about 60 minutes per year."

The spectacle relies on many things; the angle of the Sun as it sets, recent rainfall levels that feed the waterfall, and a clear sky.

"There is something spiritual in being able to visually witness the astrophysics of our Solar System play out," says Gordon. "How many points in time had to line up perfectly to make this exact moment happen? It's nature at its absolute best."

Yosemite National Park also happens to be one of the most photogenic locations on the planet, making the Horsetail Falls phenomenon a favourite for photographers, so expect a stake-out if conditions are right.

Where to go: Yosemite National Park, California
When to go: Late February
Cheapest flights: £480 (London-San Francisco)

6. SEE COLOURFUL LIGHTS IN THE NIGHT SKY

The Northern Lights are more familiar, but the Southern Lights are well worth a visit too. "Dunedin in New Zealand is probably the easiest place to go if you want to see the Southern Lights, but it's only got about as much chance as northern Scotland or England," says Dr Melanie Windridge, author of *Aurora: In Search Of The Northern Lights*. Other good locations include Ushuaia, South Georgia Island, the Falkland Islands and Antarctica. "The trouble with the Southern Lights is that they happen mainly over the ocean or in Antarctica," says Windridge.

Auroras occur when charged particles emanating from the Sun strike atoms in Earth's atmosphere, causing the electrons of the atoms to move to a higher-energy state. "When they hit oxygen they emit green, and also red higher up, while nitrogen emits blue and purple colours," says Windridge.

Where to go: Dunedin, New Zealand
When to go: March-September
Cheapest flights: £1,000 (London-Dunedin)

7. OBSERVE HUNDREDS OF SHOOTING STARS

When comets tumble through the Solar System, they leave dust and rock in their wake. As Earth orbits the Sun, its path takes it through this debris. These chunks of space rock burn up as they pass into Earth's atmosphere, causing a mesmerising light show. Although you can see a shooting star on any given night, there are a number of predictable meteor showers throughout the year. In December, stargazers watching the Geminids meteor shower can enjoy more than 100 shooting stars an hour. Meanwhile, May's Eta Aquariids and October's Orionids are worth a look – both are leftovers of the last visit of Halley's Comet in 1986. However, the top choice is August's Perseids, whose meteors often leave mesmerising trails in the sky. They're the leftovers of Comet Swift-Tuttle's passage through the Solar System in 1992.

"Your best chance to see shooting stars is after midnight because then you are on the nightside of Earth as it hits the meteors head-on," says John Barentine, program manager at the International Dark-Sky Association in Phoenix, Arizona.

Where to go: Dark Sky Parks (**darksky.org**)
When to go: August or December

PHOTOS: GETTY X2, ALAMY

8. WITNESS A DESERT SUPERBLOOM

Occasionally, the normally arid Mojave Desert, Sonoran Desert and Chihuahuan Desert will burst into a carpet of yellow, purple and pink flowers. This is a superbloom, and it happens if there's significant rainfall between September and January.

"Each big bloom is different – it all depends on how much rain falls, and where," says Ed Madej, a retired geographer, botanist and volunteer researcher at Death Valley National Park. "There's one substantial wildflower bloom every 5.3 years on average, and a superbloom on average once every 11.2 years."

Where to go: Death Valley National Park, California
When to go: February-March
Cheapest flights: £525 (London-Las Vegas)

9. WATCH ROCKETS LAUNCHING

"Every launch is very impressive and exciting because you don't know what will happen until the last moment," says Dr Ken Kremer, a science journalist and veteran of over 80 rocket launches. "You hear the fire and fury for several minutes – seeing a launch in person is a billion times better than watching on TV."

You could do worse than visiting NASA's Kennedy Space Center in Florida, or Wallops Flight Facility in Virginia. The current hot ticket, though, is going to watch a SpaceX reusable rocket launch, then land back at Cape Canaveral.

Where to go: Wallops Flight Facility, Virginia or Kennedy Space Center, Florida
Best time to go: Check **kennedyspacecenter.com** or **nasa.gov**
Cheapest flights: £450/£550 (London-Orlando/London-Washington, D.C.)

PHOTOS: GETTY X2, NATIONAL GEOGRAPHIC IMAGES

10. CHASE STORMS IN TORNADO ALLEY

"I've been a storm chaser and spotter since I was little," says Nicholas Langley from the group Tornado Alley Chasers and Spotters. "I would sit outside my house in Tennessee watching storms roll in. It fascinates me how clouds can form out of thin air, then explode into monster supercells."

A tornado is caused by updraughts and downdraughts of unstable air during a thunderstorm, when a wind shear tilts to form an upright vortex.

However, storm chasing comes with huge risks, particularly traffic accidents. "You get tunnel vision out there and you don't see the surrounding area – you just see the tornado," he says.

Tornado Alley is generally regarded to include the US states of Texas, Oklahoma, Kansas and Nebraska. Tornadoes are typically active in those states between March and late-May.

Other areas of the world where violent tornadoes are frequent include an area of the Pampas lowlands in Argentina, Paraguay and southern Brazil, and coastal Bangladesh on the Bay of Bengal.

Where to go: Texas, Oklahoma, Kansas or Nebraska
Best time to go: March-May
Cheapest flights: £780 (London-Oklahoma City)

DISCOVER MORE

For more fascinating features about the natural world, pick up a copy of our sister title *BBC Wildlife*, available in good newsagents.

HURTIGRUTEN

OUR NORTHERN LIGHTS PROMISE

We'll give you a FREE VOYAGE if the Northern Lights don't occur on your 12-day voyage with us along the beautiful Norwegian coast

On a journey with Hurtigruten, the Aurora Borealis comes to you. Our ships sail in the Arctic Circle in Norway, directly under the Auroral Zone.

From the convenience of our observation decks, you'll get a front-seat view of the lights for free, for as often and for as long as they appear.

We've been sailing under Norway's Northern Lights since 1893, no one knows them like we do.

- Visit 34 charming ports northbound and southbound from Bergen to Kirkenes and back again
- Exciting optional excursions such as whale watching, king crab safari, and husky dog sledding
- Freshly-sourced food and delicious menus on board inspired by authentic Nordic cuisine

CALL: 0203 553 9598

CONTACT YOUR PREFERRED TRAVEL AGENT

www.hurtigruten.co.uk

ABTA V7545

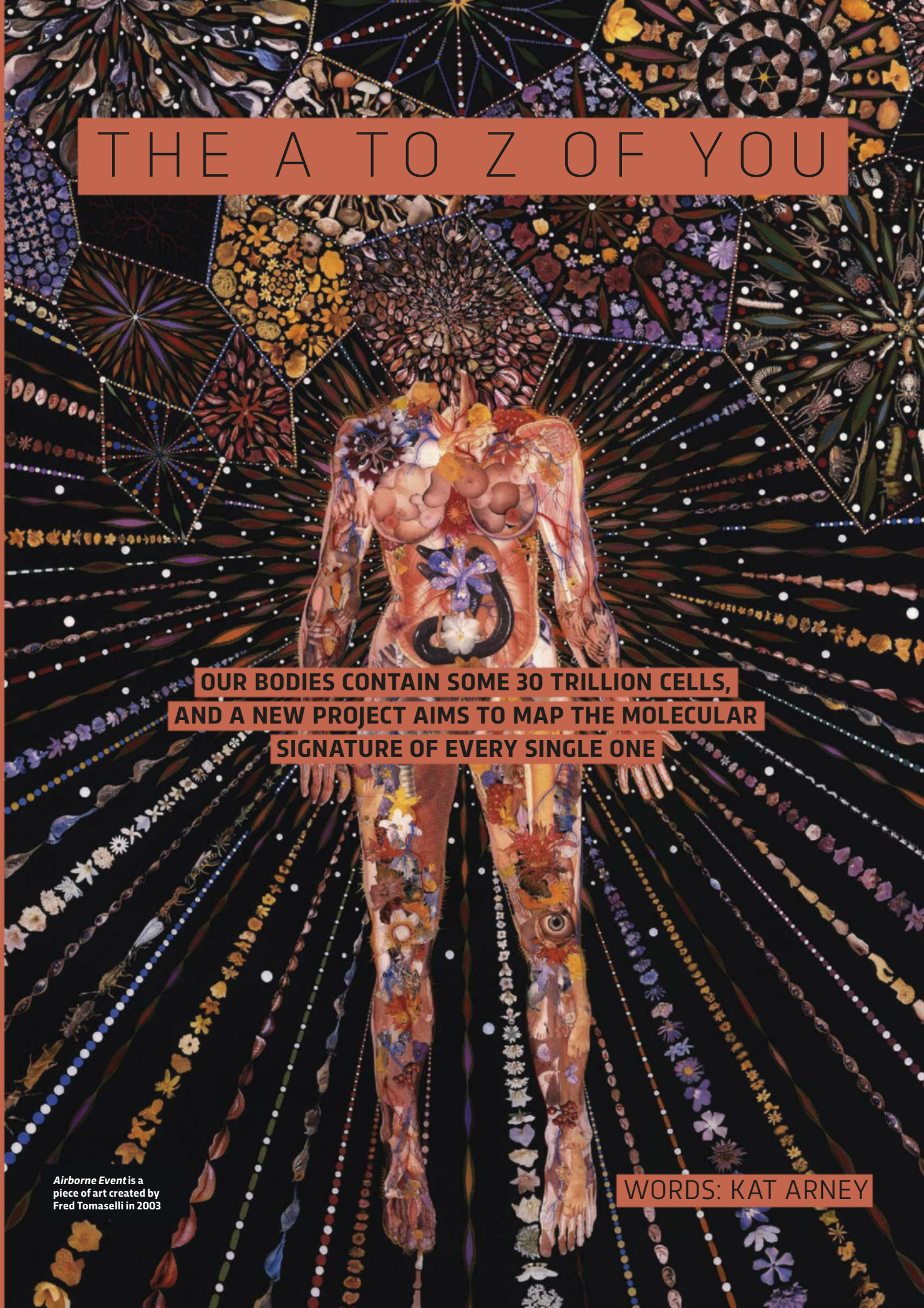
12-DAY CLASSIC ROUND VOYAGE INCLUDING FLIGHTS AND FULL BOARD

FROM **£1,193pp**

Northern Lights Promise is valid on all 12-day Norway coastal voyages from 1 October 2017 – 31 March 2018. Full terms and conditions apply. Please see website for details. From prices quoted are in GBP and are per person, based on full occupancy of an inside two-berth cabin, on a full-board basis. Single supplements may apply. Cabins and excursions are subject to availability. Hurtigruten operates a flexible pricing system and prices are capacity controlled, correct at time of booking. Not included: travel insurance, luggage handling, optional excursions or gratuities. Flights booked with Hurtigruten are economy, ATOL protected (ATOL 3584), and include all current taxes and charges. All itineraries are subject to change due to local conditions. See website for the full itinerary. Full booking terms and conditions available online at www.hurtigruten.co.uk.

THE A TO Z OF YOU

OUR BODIES CONTAIN SOME 30 TRILLION CELLS, AND A NEW PROJECT AIMS TO MAP THE MOLECULAR SIGNATURE OF EVERY SINGLE ONE



Airborne Event **is a piece of art created by Fred Tomaselli in 2003**

PHOTO: FRED TOMASELLI - AIRBORNE EVENT 2003 - COURTESY OF THE ARTIST AND JAMES COHAN NEW YORK

WORDS: KAT ARNEY

Mapping the human body is one of biology's oldest endeavours. By studying the battered bodies of Roman gladiators, the 2nd-Century philosopher-surgeon Galen of Pergamon wrote medical texts that stood as the pinnacle of anatomical knowledge for more than 1,000 years, until the Flemish doctor Andreas Vesalius came up with more accurate works. But it wasn't until the invention of the first practical microscope in the mid-1600s, a century after Vesalius's death, that curious scientists could finally begin to study cells – the building blocks that make up our tissues and organs.

Just as studying the tiniest subatomic particles has helped physicists to unravel the workings of the cosmos, so biologists have found that zooming in on our individual cells can reveal new insights into the human body. For a long time, this has been the domain of pathologists, studying the physical appearance of cells and tissues, along with a relatively limited number of molecular markers.
But, backed by the exciting new science of single-cell genomics, a project called the Human Cell Atlas is aiming to create the ultimate inventory of the human body, mapping every single one of our cells in intricate detail. And the resulting guidebook could revolutionise our understanding of health and disease.

CELLULAR SCIENCE

It's long been clear that cells in different organs look and behave in their own distinctive ways. For example, spherical immune cells are primed to recognise infections, while spidery nerve cells crackle with hundreds of connections. Nevertheless, each cell still has the same basic set of instructions in the form of the human genome, encoded within our DNA. The thing that makes each cell type different is the particular set of genes active within it, producing molecular messages called RNA. And because a particular pattern of gene activity will be unique to a specific cell type, the RNA made within it will be unique too, acting as a kind of molecular 'fingerprint'.

For several decades, researchers have been able to measure the activity of genes in different cell types (known as gene expression) by mashing up millions of cells and analysing the different RNAs, getting a read-out of which genes are switched on and which are off.

Yet this is only an average, and this method can't pick up differences between individual cells. It's like looking at a crowd from a distance and only seeing a colourful blur, rather than the exact hue of each person's shirt. But thanks to recent advances in technology, we can now zoom right in to look at gene activity in a single cell (see diagram, below).

A typical human body contains around 30 trillion cells, but while it is often said that there are around 200 different types, more detailed molecular analysis has revealed that this is a massive underestimate. Is every cell in the liver exactly the same, or have we only been measuring averages? What about the billions of neurons in the brain, or the multitude of distinct immune cells? These questions provided the spark for the Human Cell Atlas, which aims to map gene expression patterns in billions of individual cells.

THE JOURNEY BEGINS

The idea flickered into life in 2012 when geneticist Dr Sarah Teichmann came to the Wellcome Trust Sanger Institute near Cambridge to set up a research group studying gene activity in single cells in the mouse immune system. Over coffee and conversation with her new colleagues, she realised that her techniques might solve a much bigger challenge.

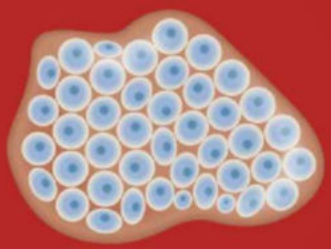
"Despite centuries of microscopy, we don't actually fully understand the different cell types in the body," she says. "When I came to the Sanger Institute we started bouncing ideas around. It was a bit utopian because the technology just wasn't there yet, but we thought what if someday it would be possible to atomise a human body – take a human and look at all their cells. Of course, you're not vaporising a whole person, but we thought we could take tiny samples from many different people and stitch it all together into a kind of universal atlas."

With trillions of cells to analyse, this isn't the kind of task that a single laboratory, or even a single institute, can handle alone. Teichmann and her colleagues soon realised that a number of other researchers were starting to have the same thoughts as them – notably Dr Aviv Regev at the Broad Institute in Massachusetts – and began to build an international consortium of single-cell enthusiasts ranging from geneticists and molecular biologists to surgeons and ➤

PHOTOS: SCIENCE PHOTO LIBRARY, WELLCOME IMAGES X2. ILLUSTRATIONS: ACUTE GRAPHICS

HOW IT WORKS: SINGLE-CELL GENOMICS

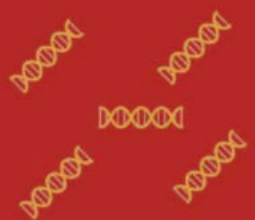
In order to measure the gene activity in a single cell, you need to isolate its RNA – the molecular messages produced when genes are switched on. By comparing the sequences of these messages with the whole genome (the complete set of DNA contained inside every cell), researchers can figure out which genes are being expressed in any particular cell at that time.



1 Separate tissue sample into single cells, using high-powered focused laser beams, enzymes or other techniques.

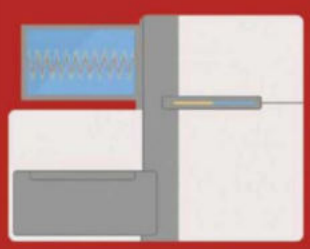
2 Break open each cell to release the RNA messages.

Modern images of blood cells taken with scanning electron microscopes (main image) offer far more detail than earlier microscope images, like these published in 1845 (inset)



3 Convert the RNA into DNA – this process is known as reverse transcription.

4 Amplify the DNA thousands or even millions of times to get enough material to sequence.



5 Read the DNA using next-generation sequencing tech.

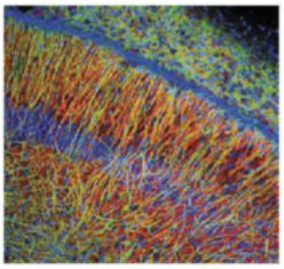
6 Analyse results to work out which genes are active, producing a gene expression profile for that cell. Repeat for cells around the body!

SENSATIONAL CELLS

THE HUMAN CELL ATLAS IS INITIALLY FOCUSED ON FIVE TYPES OF CELL...

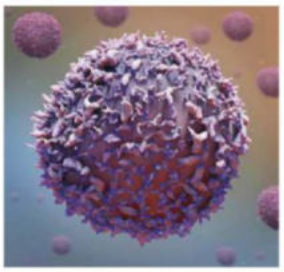
Brain

The brain is probably the most complex organ in the body, made up of more than 86 billion nerve cells (neurons). By mapping all the patterns of gene activity in different brain cells, researchers hope to understand how neurons wire up and communicate, and what goes wrong in psychiatric and neurodegenerative illnesses.



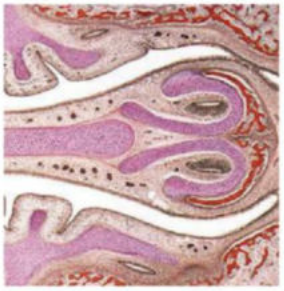
Immune system

There are hundreds of types of cell in the immune system alone, each with distinct roles in spotting and responding to infections or disease. Analysing each cell type will reveal the changes that happen as the immune system fires into action, and will shed light on autoimmune conditions and allergies.



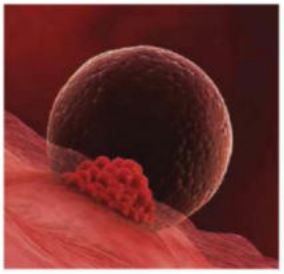
Epithelial cells

Epithelial cells are one of the most versatile cell types. They make the linings of our organs, ranging from the tubes of the gut to the delicate air sacs of the lungs. Establishing how epithelial cells carry out such a diverse range of roles will explain how organs grow and are affected by diseases such as cancer.



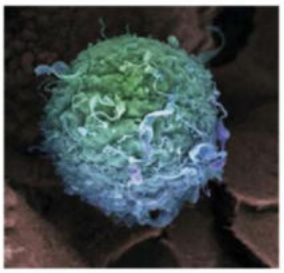
Placenta and foetus

Studying these tissues will reveal how we grow and develop in the womb, and how a healthy placenta develops to provide oxygen and nutrients. This will give us vital clues for understanding what has gone wrong in babies who are born with developmental disorders, or when a pregnancy



Cancer

By analysing gene activity in single cancer cells, researchers hope to identify the changes that trigger the growth and spread of tumours. They are also searching for clues to explain how these rogue cells can develop resistance to therapy, with the aim of finding ways to prevent the disease coming back again after treatment.



machine learning specialists. So far, the team has committed to studying four types of tissue: the brain, the immune system, epithelial tissue (which lines the surfaces of organs and blood vessels), and foetal and placental cells. As well as cataloguing the cells of healthy people, a key part of the project will be to understand how cells change their activity when we get sick, so cancer cells are on the initial list, too.

ROBOT RESEARCHERS

The scale of the Human Cell Atlas and the accuracy required means that this is no longer the kind of work that can be done by hand. To find out more about the technology involved, I visited Dr Stephan Lorenz. He heads up the single-cell genomics facility at the Sanger Institute, where a significant proportion of the work for the Human Cell Atlas will be carried out.

He shows me around several large rooms full of huge cabinets containing an army of high-tech, liquid-handling robots for preparing and processing single-cell samples, supervised by just two human staff. One impressive machine isn't so much a sonic screwdriver as

"WE CAN NOW UNDERSTAND HOW CELLS 'THINK AND FEEL' AND SEE INSIDE THE 'MIND' OF A CELL"

a sonic sampler, using sound pulses to whack precisely-measured microscopic drops of liquid from one plastic plate to another. Another can process more than 1,200 samples in 90 minutes.

"Over the last couple of years there's been an explosion of methods that allow us to measure these tiny quantities of RNA that are present in a single cell," he says. "We can now understand how cells 'think and feel' and see inside the 'mind' of a single cell. By looking at the messages in cells we can infer their function and even their identity." What's more, he explains, he can even see how individual cells in the immune system change when they are activated to fight infection, or watch the genes that are switched on and off as one cell splits into two.

Yet RNA messages aren't the only thing that gives a cell its identity. RNA carries instructions to make proteins, which build physical structures inside cells and carry out biological functions in the body (for example, digestive enzymes in the stomach or sturdy keratin proteins that make up our skin and hair). Lorenz and his colleagues are now developing methods to analyse all the proteins inside a single cell.

It currently takes about three weeks to analyse all the RNA in an individual cell, though the process is speeding up all the time. Perhaps an even bigger challenge than

A laboratory at the Sanger Institute, where a lot of the Human Cell Atlas research will be carried out

analysing all of the cells is coping with the quantity of data generated. Around 850,000 messages are sequenced per cell. Multiply that by millions of cells, and it quickly adds up.

To help with this, the Human Cell Atlas consortium secured funding from the Chan Zuckerberg Initiative (set up by Facebook founder Mark Zuckerberg and his wife Priscilla Chan) to develop ways to process and present the torrent of information coming from the sequencing labs.

Making the Atlas searchable and usable is vital if it is to become a meaningful resource for scientists. Although Teichmann doesn't yet know how the data will be presented, she does have one fun idea. "The really futuristic vision is that we will all be wearing virtual reality headsets and be able to look at a virtual body to point out parts that we want to see," she says.

MAPPING THE FUTURE

It's still early days for this incredibly ambitious project, which officially kicked off in October 2016, but Teichmann thinks it's feasible. "I would say for a draft Atlas we need to analyse between approximately 30 million and 1 billion cells," she explains. "Over the last eight years, there has been an exponential decrease in cost per cell and an exponential increase in the number of cells per experiment. If that trend continues then we are in good shape."

As well as satisfying our scientific curiosity about what we're all made of, Teichmann sees the Atlas as a source of huge potential benefits for biomedical research, revealing leads for new drugs or finding molecules that act as biomarkers for diagnosing and monitoring disease. At a deeper level, she hopes it will answer fundamental questions about the links between genes and health. As an example, she mentions the harmful change (mutation) in a gene called CFTR that causes cystic fibrosis, which affects the lungs and other organs.

"We know that CFTR is active in the lungs, but in fact is expressed in other parts of the body, too. So you could interrogate the Human Cell Atlas and find those cells, to understand why things are going wrong when it's mutated," she explains. "Or say you want to know the side effects of a drug that targets the product of a particular gene. You could search the Atlas to see where that gene is expressed – which organs, tissues and cells – and then predict what the anticipated side effects might be."

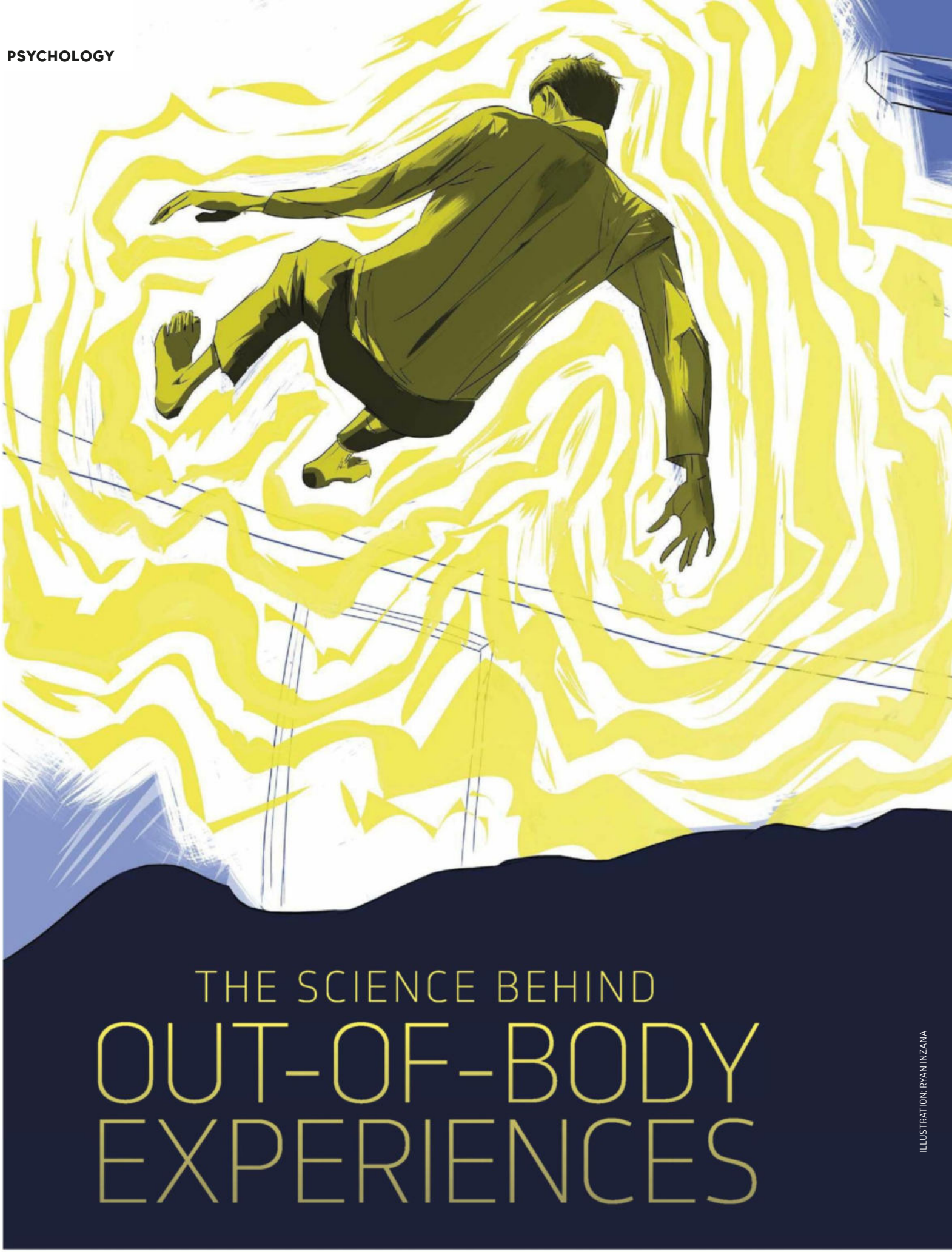
Understanding exactly what has gone wrong in a wide range of diseases, quickly identifying which cells and which molecules are misbehaving, will help doctors to diagnose conditions faster and select the most appropriate treatment with less of the guesswork that goes on at the moment.

Ultimately, Teichmann and her team see the Human Cell Atlas as a fundamental resource that will one day have an impact on almost every aspect of biology and medicine. Perhaps we could even call it Human Genome 2.0.

"I like that!" she laughs. "The Human Genome Project was all about deciphering the DNA sequence, but the Human Cell Atlas is asking what does that sequence actually stand for? How is the genetic code read out to make a human body? It really is mind-blowing!"

Kat Arney is a science writer and broadcaster who presents *The Naked Scientists* every week on BBC Radio 5 Live. Her latest book, *How To Code A Human*, is out now (£16.99, Andre Deutsch).

PHOTOS: GETTY X5, SANGER INSTITUTE



THE SCIENCE BEHIND OUT-OF-BODY EXPERIENCES

ILLUSTRATION: RYAN INZANA

Out-of-body experiences have previously been dismissed as fantasy, or hailed as evidence of the human soul. But new research suggests they could be the key to unlocking the mysteries of consciousness… WORDS: **PROF SUSAN BLACKMORE**

Have you ever felt as though you were lifting up out of your body, floating near the ceiling and looking down on the world and your own body below? If so, by definition, you've had an out-of-body experience, or OBE. This definition is important because it describes the OBE purely as an experience. This opens the question: does anything *actually* leave the body in an OBE? If it doesn't, we have to find out why OBEs happen and what's going on in the brain when one takes place. If it does, the implications are profound. If someone could truly leave their body, then mind or consciousness must be able to exist beyond the brain and even potentially survive death. If this were the case, much of science as we know it would have to be overthrown. Let's take a look at OBEs and the research surrounding them.

Most people who have OBEs are, at least briefly, convinced that their soul, spirit or astral body has really gone travelling, thanks to the realistic nature ▸

"Although the experience can happen at any time, when walking, washing-up, or even riding a bike, most OBEs occur when people are relaxed and lying down"

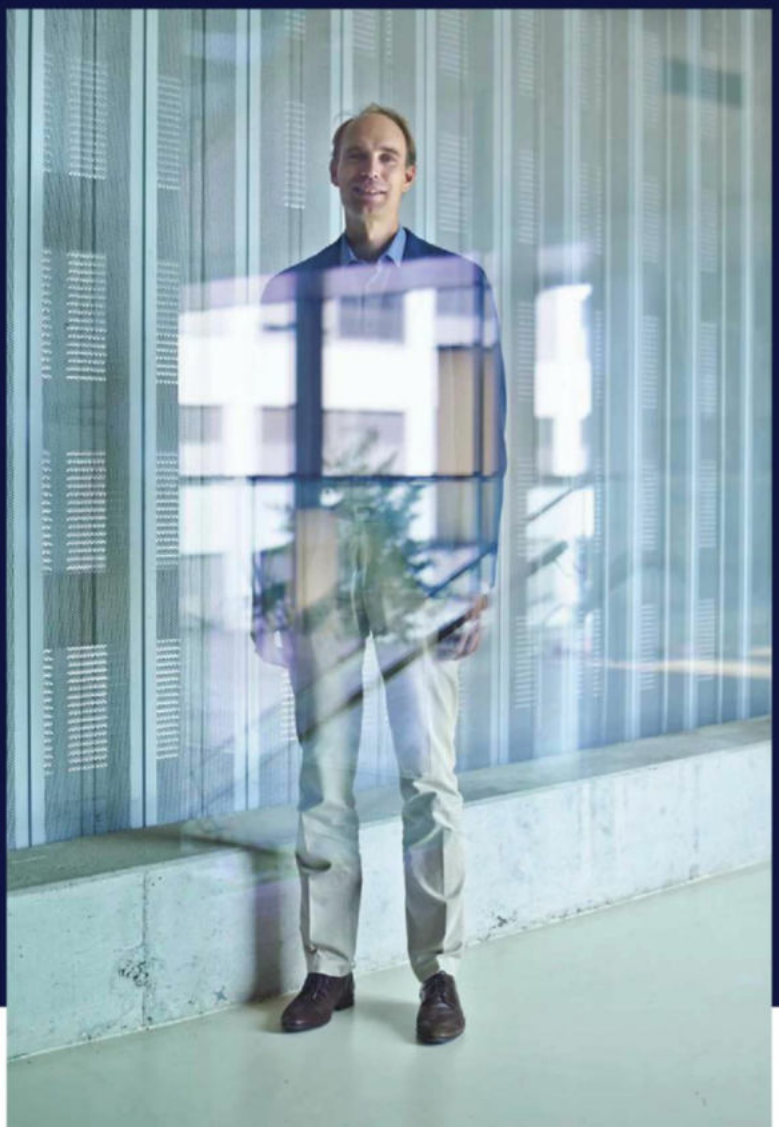
of the experience. About 12 to 20 per cent of the population in many different countries have had the experience at least once, with a few able to induce it at will.

Although the experience can happen at any time, when walking, washing-up, or even riding a bike, most OBEs occur when people are relaxed and lying down. Some happen on the verge of sleep, especially in combination with sleep paralysis – an unpleasant feeling of waking up and finding yourself unable to move. Others happen as part of a near-death experience. But why?

Until recently the most common explanation was 'astral projection'. This idea developed in the 19th Century as part of Theosophy, a scheme loosely based on Hindu and Buddhist teachings that involved seven 'bodies of man', ranging from the physical body right up to higher spiritual bodies. In between is supposed to be the 'astral body', a subtle vehicle of consciousness that can separate temporarily during life and permanently at death, leading to life after death.

In the 20th Century, psychical researchers and parapsychologists tried, but failed, to detect astral bodies using psychic mediums or a variety of physical instruments. They set up extrasensory perception (ESP) experiments to test whether OBErs could see targets placed in distant rooms, but no convincing results were ever obtained and OBEs remained a dubious topic of research on the fringes of the paranormal.

BELOW: **Olaf Blanke induced an out-of-body experience in a patient**



ELECTRODES AND EPILEPSY

But with the turn of the century, everything changed. In a hospital in Switzerland, neurosurgeon Prof Olaf Blanke was carrying out a tricky operation on a woman whose severe epilepsy could not be treated unless the focus of her frequent seizures was found. To locate it, an array of electrodes was positioned under the dura, the strong membrane surrounding her brain, so that different spots could be electrically stimulated. She remained awake throughout because there are no pain receptors in the brain itself. To the surgeon's immense surprise, when he gently stimulated a spot near the right temporoparietal junction (TPJ) his patient described sensations of falling and sinking, as well as bodily distortions. With stronger stimulation, she felt as if she was floating near the ceiling. By repeating the process, her OBEs could be repeatedly elicited and controlled. As the famous paper in the journal *Nature* declared: "The part of the brain that can induce out-of-body experiences has been located".

You might think this proves that an OBE is a perfectly natural phenomenon, requiring no spirits, souls or astral bodies. Yet some people disagree, arguing that this special spot is the place from where the astral body leaves, or through which God communicates with our consciousness. To provide a better explanation, we need to understand a bit more about the TPJ. This region, located at the part of the brain where the temporal and parietal lobes meet, constructs our sense of self and maintains our 'body schema'. This is a constantly updated model of our whole body that is essential for us, as for any other animal, to keep track of where we are and what we are doing. Closely related to the body schema is our body image – our sense of personality and appearance. At the TPJ, information flows in from the senses and the memory to construct a rich impression

PHOTO: STEPHAN FLOSS. ILLUSTRATION: RYAN INZANA

of who we are, including our sense of inhabiting our own body, and being able to control it.

Now the surgeon's discovery begins to make sense. If the body schema is disrupted by electrical stimulation, it would fail to properly track what the body is doing and so might drift from the body's actual location. This would explain the distortions, like getting larger or smaller, or limbs growing and shrinking. These sensations occur with direct intervention in the brain, but also happen on the verge of sleep, with the use of certain drugs and before spontaneous OBEs. With serious disruption the body schema might split in two and this, researchers have suggested, is the cause of the OBE.

FAILURE OR SKILL

This gives a rather bleak account of OBEs, attributing them to 'failed integration at the TPJ' or a 'break-down of body processing'. So are the experiences a ▶

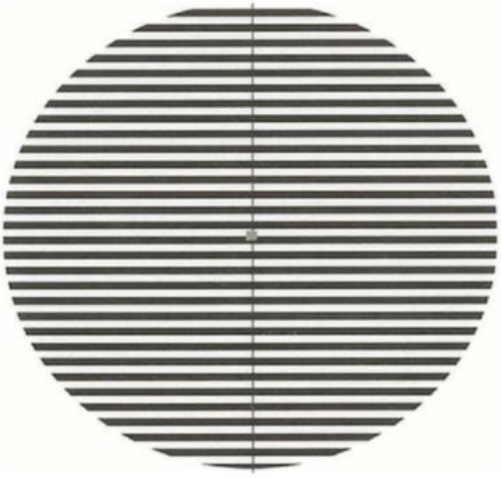
COULD YOU HAVE AN OBE?

Almost anyone can have an OBE but certain characteristics make it more likely. One is 'psychological absorption'. Scoring high on this measure means you are easily engrossed in films, books or music, ignoring everything else around you. You may be susceptible to hypnosis, have a rich fantasy life and remember having imaginary playmates as a child.

Another is 'positive schizotypy'. This sounds as though it's related to schizophrenia and in a way it is. The idea is that everyone lies on a continuum from low to high schizotypy. High schizotypes have unusual dissociative experiences, disorganised thoughts, flat emotions and unstable moods, but are more imaginative and creative too. They include many writers, artists and poets, as well as OBErs. A third indication is 'temporal lobe lability', meaning the brain's temporal lobes are more unstable or unpredictable. Labile types report more OBEs but also more lucid dreams, sleep paralysis, visions and hallucinations.

These connections have been known for some time but a new discovery is revealing more about the underlying brain function. OBErs react differently to the 'pattern glare task'. Look for a minute at the pattern of black and white stripes below. If you see just black and white stripes, that's fine. But if you are susceptible to pattern glare the stripes will jiggle and shift, with strange shapes and illusory colours drifting across the stripes. In this case you are more likely to have OBEs.

This test is thought to reveal cortical hyper-excitability, meaning that those who see the illusions have more easily excitable brains. Hyper-excited visual systems produce tunnel experiences, excited auditory systems produce the whirring and grinding noises associated with sleep paralysis, and when our vestibular systems go wild we feel like we're floating and flying. In other words, this tendency to excitation leads to classic OBEs.



OUT-OF-BODY IN VIRTUAL REALITY

Can you imagine becoming convinced that a pink, rubber hand is your own? Unlikely as it seems, this is the famous 'rubber hand illusion'. The person's own hand, lying next to a rubber hand, is concealed from view by a screen. If both hands are stroked simultaneously, people start to feel the touch as though it is on the rubber hand.

Bigna Lenggenhager, at the University of Zurich, has managed to create a 'whole body illusion' using virtual reality. She places a camera two metres behind a participant and gives them a head-mounted display to wear, so they are looking at their own back. When the experimenter gently strokes the participant's back, they can watch as well as feel it. Gradually the sensation shifts towards the virtual body.

In Sweden, neuroscientist Henrik Ehrsson uses a different method to create a similar effect. A camera is again positioned two metres behind a participant, but this time their chest is stroked in synchrony with a stick moving up and down in front of the cameras. With this method, people feel they have moved backwards towards the cameras. These may just be tricks but their effect can be profound. When the illusion is strong, body temperature drops, pain is felt less intensely, and threatening the real body with a knife produces a weaker reaction. The illusions have been induced inside an fMRI scanner, revealing that changes in activity in the brain's temporoparietal junction reflect changes in self-location. These illusions are not the same as full OBEs, yet they reveal how our sense of being inside our own body can be manipulated. And this may explain how we can sometimes be convinced that we are outside our body.

"It may turn out that OBEs are linked with the important social skill of being able to understand someone else's perspective"

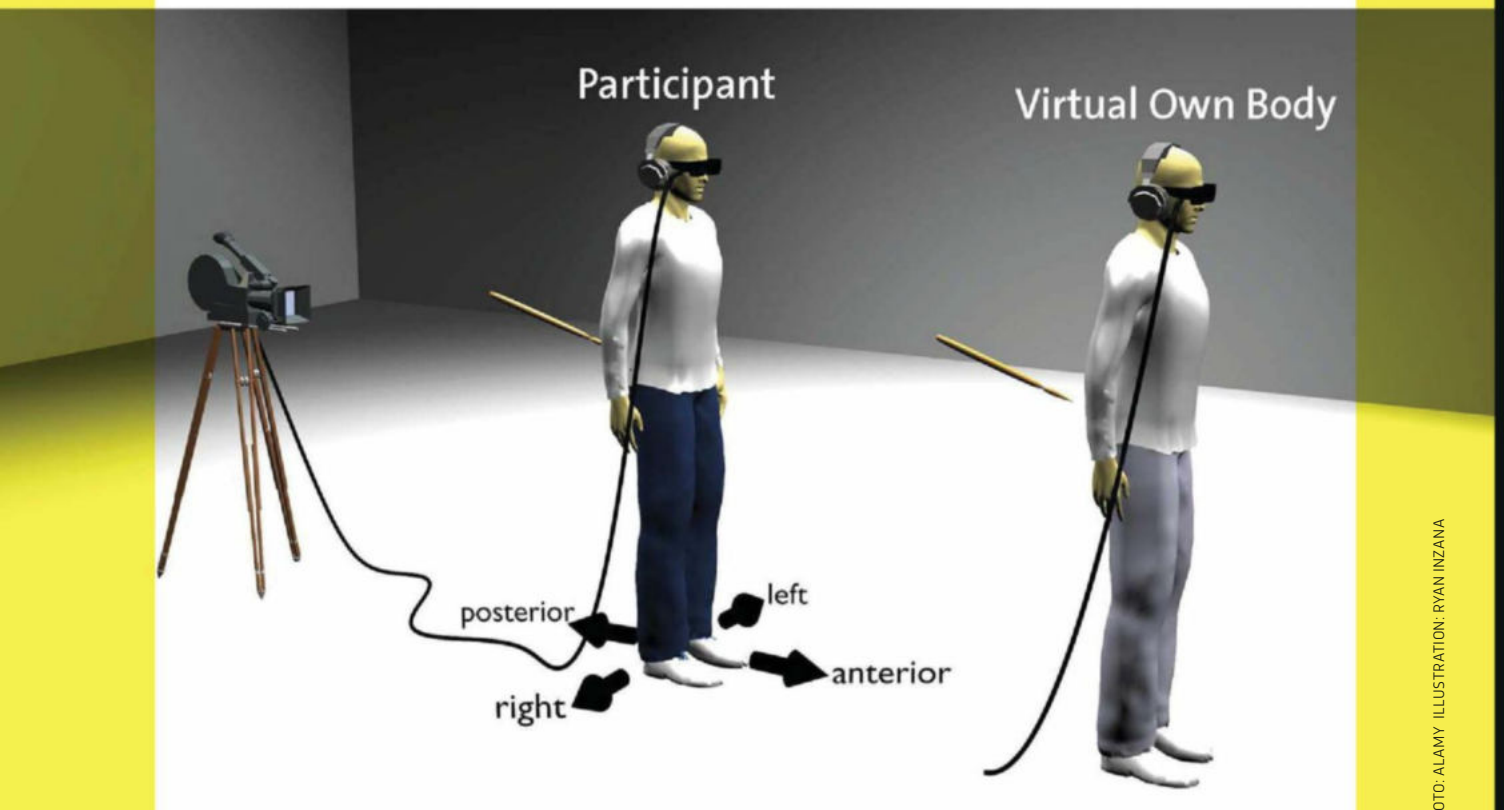


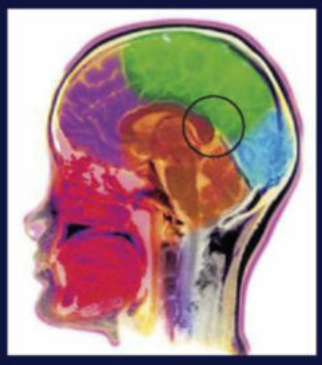
PHOTO: ALAMY ILLUSTRATION: RYAN INZANA

sign of something wrong, or even of mental illness? Although there are some links with pathology, the evidence says no. US researchers gave an extensive questionnaire called the 'Profile of adaptation to life' to several hundred OBErs and found them to be as healthy as, or even more healthy than, the average American; a study in the UK compared a small group of patients with schizophrenia to a control group and although the schizophrenics reported more bizarre experiences of various kinds, the two groups included the same number of OBErs.

A more positive way to understand OBEs fuels a recent debate between those who think they represent a failure and others who say they reveal a skill. The earliest psychological theories suggested that imagery might be the relevant skill but many experiments showed no obvious differences in richness or vividness of imagery. Some small differences were found in the ability to switch viewpoints, for example between imagining a scene from eye level or from a bird's eye view, and OBErs were found more often to dream in bird's eye view. These were clues leading to recent research showing

LEFT: **Experiments with cameras and headsets have allowed scientists to manipulate our sense of location**

RIGHT: **The brain's temporoparietal junction (highlighted with a black circle) is the region that seems to be associated with OBEs**



the relevance of what is called 'perspective taking'. This is the ability to see things from someone else's point of view and is related to empathy. Interestingly, this ability also depends on areas of the brain close to the TPJ. So it may turn out that OBEs, far from being a failure, are linked with the important social skill of being able to understand someone else's perspective.

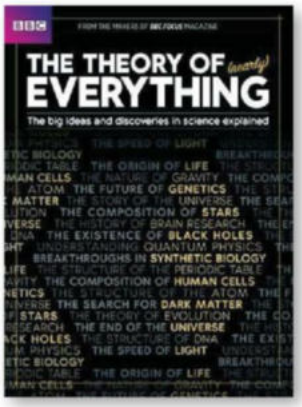
It is still early days for serious OBE research but now it has begun we may find that an experience that was once dismissed as fantasy and ignored by mainstream science is now contributing to our understanding of consciousness and the nature of self.

Prof Susan Blackmore is a psychologist, lecturer and writer specialising in consciousness. Her latest book is *Seeing Myself: The New Science Of Out-Of-Body Experiences* (£14.99, Robinson).

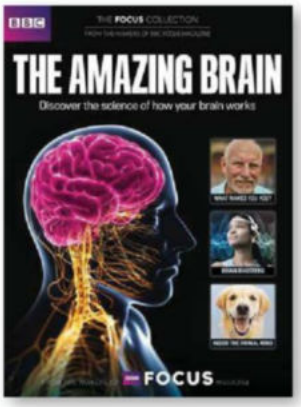
FROM THE MAKERS OF

BBC FOCUS MAGAZINE

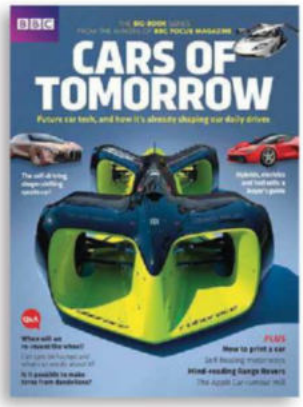
ONLY £9.99 EACH INC FREE UK POSTAGE*



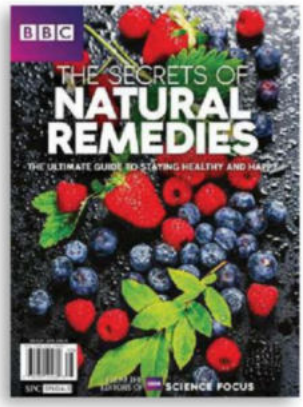
This special issue explains the fundamental concepts of science, and reveals the latest cutting edge research that will change our world.



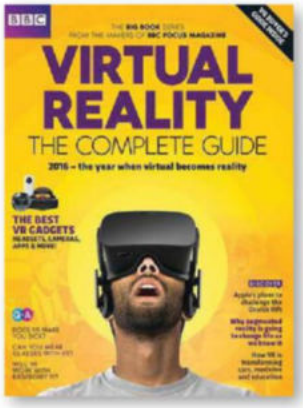
Learn about the extraordinary abilities of the human brain, the latest research into mental health, and how we can make ourselves smarter in the future.



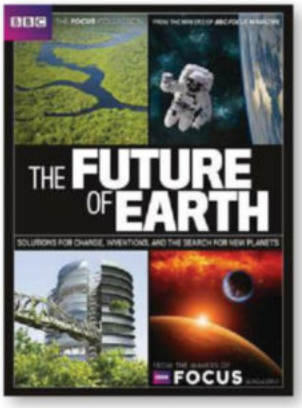
Featuring articles on virtual reality showrooms, how to print a car, buyer's guides to hybrid, electric and fuel cell vehicles and much more.



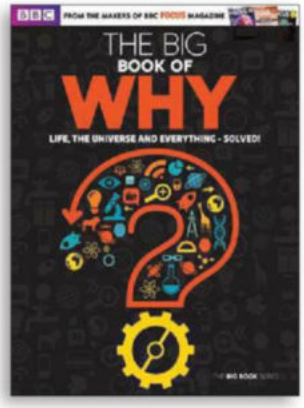
From acupuncture to yoga, argan oil to zinc, we ask scientists which techniques and treatments will help you live a happier, healthier life and which you ought to avoid.



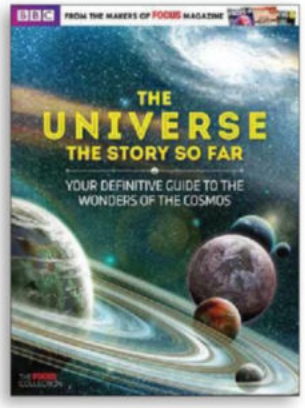
Inside: VR buyer's guide including headsets, cameras and more; the best free apps; and meet Palmer Luckey, founder of Oculus Rift.



Explore the current state of Earth, how we can protect it from global warming and natural disasters, and what would happen if we left to colonise another planet.



The Big Book Of Why? solves a wide range of scientific questions and conundrums about how life works. With answers provided by a crack team of experts!



This special edition takes you on a journey from the pioneers who first described the Universe to the extraordinary missions exploring distant worlds today.

***Subscribers to *BBC Focus* Magazine receive FREE UK postage on these special editions.**

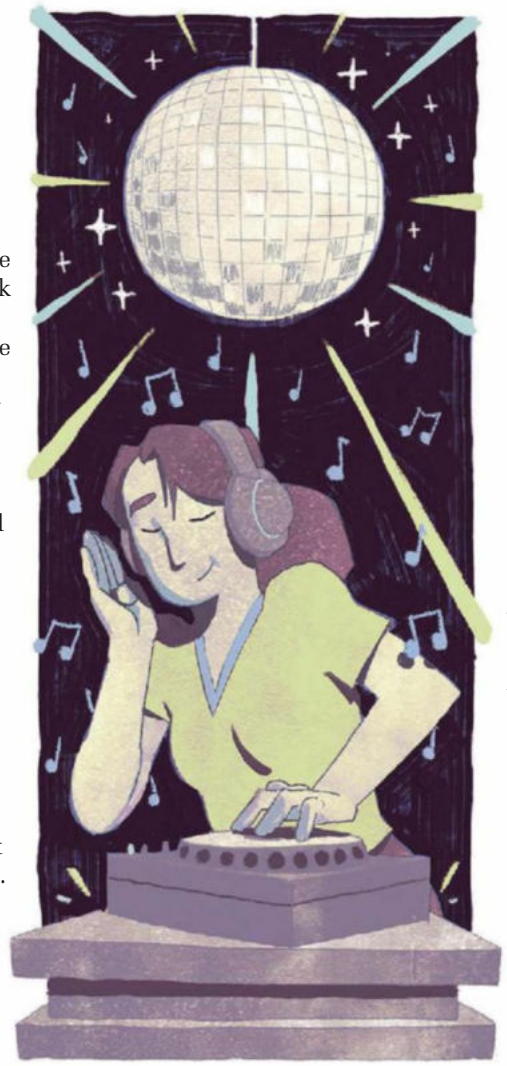
Order online: **www.buysubscriptions.com/focuscollection**

or call us on **0844 844 0257**† and quote **FOCSPEC**

†Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am to 8pm weekdays and Saturday 9am to 1pm. *Subscribers to *BBC Focus* Magazine receive Free UK Postage on these special editions. Prices including postage are: £11.49 each for all other UK residents, £12.99 each for Europe and £13.49 each for Rest of World. Please allow up to 21 days for delivery.

HELEN CZERSKI ON... BAD VIBRATIONS

"THE TASK IS TO ISOLATE THE DECKS FROM THEIR MECHANICAL ENVIRONMENT"



There is an invisible line around every performance space that separates two worlds. On one side live the magic of performance, slick stage sets and an audience whose shared reactions almost merge them into a single organism. On the other side, there's a glorified garden shed made of temporary wooden walls, webs of gaffer tape and dark corners in which lurk assorted equipment and used coffee cups.

I was recently backstage at a music and science festival, in a gigantic tent in a field. The DJ from the previous evening had vanished into the night, and I was about to give a science talk. I put my laptop down on top of three concrete paving slabs on a wooden table, then wondered why anyone had hoiked these weighty monsters up all the rickety wooden steps to perch them on a table. The technician was amused that I had noticed. "They're for the DJs," he said, "it protects their decks from the vibrations".

My first reaction was that anything that solid would surely transmit vibration extremely well, but there's more to it than that. Turntables for vinyl records have always been sensitive to vibration. But when vinyl disappeared, DJs couldn't let the turntables go, so the electronic world had to provide something called a jog wheel, which lets the DJ mix music in the same manner. Unfortunately, it turns out that jog wheels are also pretty sensitive. When the whole event is based on colossal speakers and several hundred people dancing, that's a problem.

The task is to isolate the decks from their mechanical environment. The floor and the speakers are pounding, pushing hard on everything that they touch. One solution is to absorb the travelling vibrational energy and turn it into harmless heat. This is what damping does – things like padding and shock-absorbers. The vibration can travel in, but there's an energy tax extracted as it travels through, and after some distance, the energy has all been dissipated. The problem is that sufficient damping is either very expensive or very wobbly.

The other solution is far more elegant. In any travelling vibration, a force pushes on particles until they move a tiny distance before being pushed back into place. But the relationship between the force and the particle speed is crucial. As the vibration travels from one material into a new one, the force is the same, but the particles respond differently. That means only a fraction of the vibrational energy is transmitted – the rest is reflected back.

The better matched the materials, the more energy is transmitted. If they're badly mismatched, you've just built a mechanical shield. The crucial property here is called 'impedance'. Air has a lower impedance than solid materials, so one solution for the DJs is a hovering airborne table, leaving an air gap between the deck and the stage. That one comes with some practical problems when you live on a planet, though. But concrete is at the other end of the scale, very dense and stiff, with a very high impedance.

So in the music tent, vibrations could be humming through the stage, floor and table, but when they hit the concrete slabs, there's a mismatch. Most of the energy is reflected back, so the decks are protected from the humming environment they've created. Concrete can transmit vibrations beautifully, if the vibrations get into it – but if it's sitting on a wooden table, they can't.

So it isn't just that the magical world in front of the stage never sees the scruffy world that's hidden behind – the hidden heart of the musical system is also oblivious to the frantic world in front. I'm not generally a supporter of ignorance, but in this case it seems it really is bliss.

Dr Helen Czerski is a physicist and BBC presenter. Her latest book is *Storm In A Teacup*.

NEXT ISSUE: STATIC ELECTRICITY

ILLUSTRATION: KYLE SMART

FROM THE MAKERS OF BBC HISTORY MAGAZINE

Collector's Editions

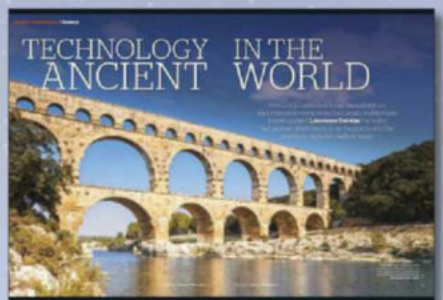
THE STORY OF SCIENCE & TECHNOLOGY

This collector's edition from *BBC History Magazine* explores the history of science and technology, from the earliest Greek gadgets to the modern exploration of space. Meet astronomers, engineers, experimenters and inventors - the trail-blazing thinkers who shaped our world

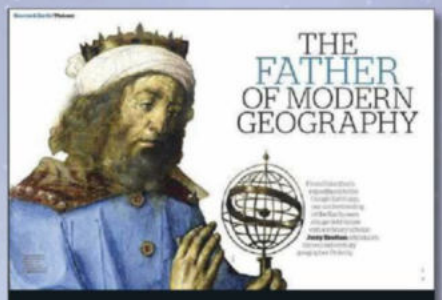
Inside you will find:

- An informative timeline of the history of science
- The lives and discoveries of Galileo, Ptolemy, Brunel, Watt, Newton, Boyle and many more
- Expert writers on the world's greatest scientific advances
- Insights into over 2,000 years of scientific ideas and inventions, people and personalities

ONLY £9.99 PLUS P&P*



Global milestones in technology



Landmark discoveries

Inventors and pioneers

Order online **www.buysubscriptions.com/science** or call us on **03330 162 138**† and quote **PRINT1**

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8.00am -6.00pm weekdays and 9.00am – 1pm Saturday for orders only. *Prices including postage are: £11.49 for all UK residents, £12.99 for Europe and £13.49 for Rest of World. Please allow up to 21 days for delivery.


DR ALASTAIR GUNN
Astronomer, astrophysicist


ALEX FRANKLIN-CHEUNG
Environment/ climate expert


DR PETER J BENTLEY
Computer scientist, author


PROF ALICE GREGORY
Psychologist, sleep expert


PROF MARK LORCH
Chemist, science writer


CHARLOTTE CORNEY
Zoo director, conservationist


DR HELEN SCALES
Oceans expert, science writer


DR CHRISTIAN JARRETT
Neuroscientist, science writer


EMMA DAVIES
Heath expert, science writer


LUIS VILLAZON
Science/tech writer


DR AARATHI PRASAD
Biologist, geneticist


PROF ROBERT MATTHEWS
Physicist, science writer

YOUR QUESTIONS ANSWERED

SEPTEMBER 2017 | EDITED BY EMMA BAYLEY

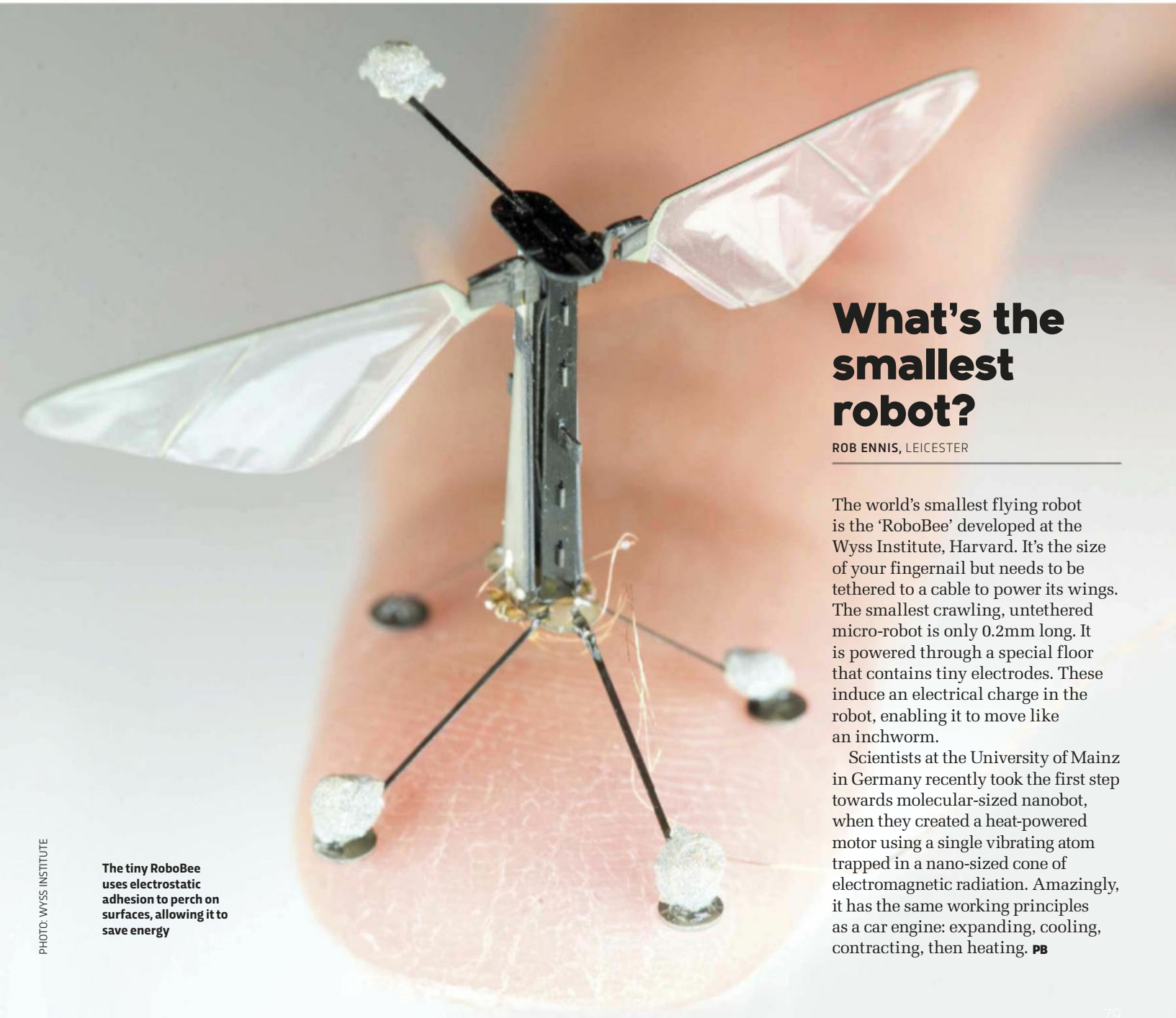


PHOTO: WYSS INSTITUTE

The tiny RoboBee uses electrostatic adhesion to perch on surfaces, allowing it to save energy

What's the smallest robot?

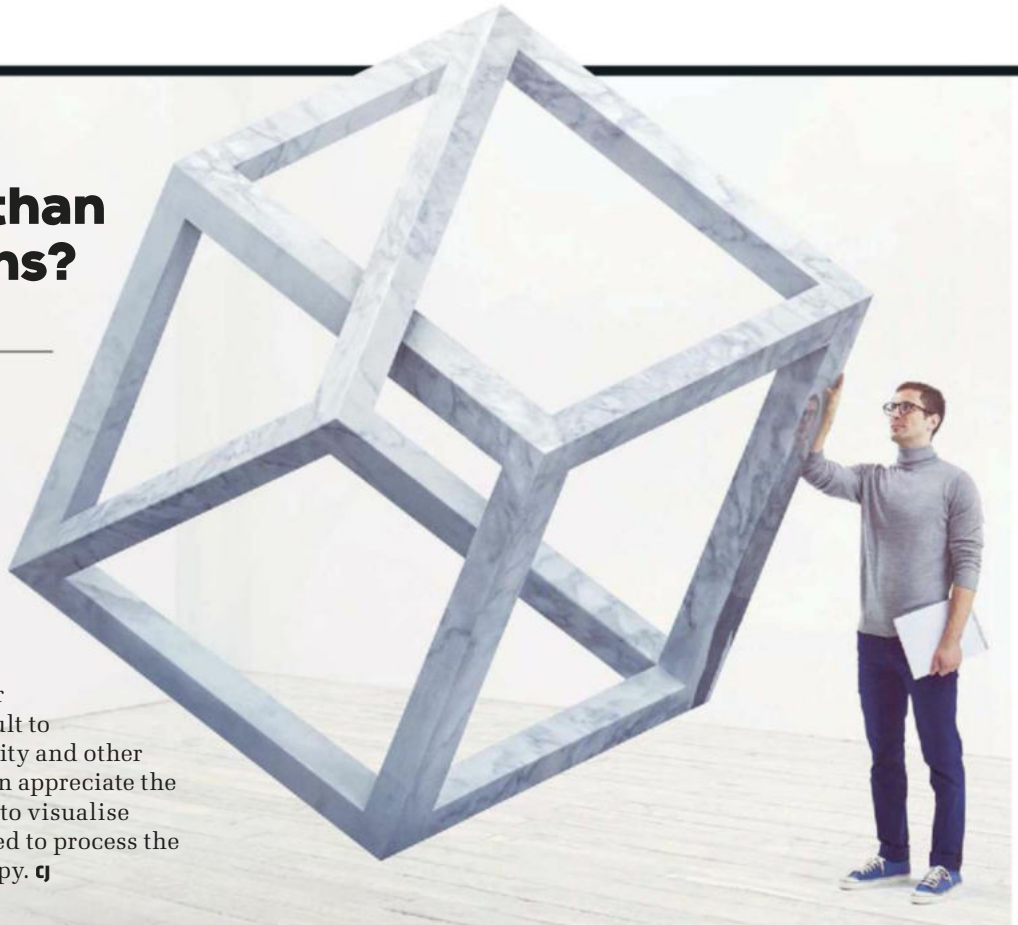
ROB ENNIS, LEICESTER

The world's smallest flying robot is the 'RoboBee' developed at the Wyss Institute, Harvard. It's the size of your fingernail but needs to be tethered to a cable to power its wings. The smallest crawling, untethered micro-robot is only 0.2mm long. It is powered through a special floor that contains tiny electrodes. These induce an electrical charge in the robot, enabling it to move like an inchworm.

Scientists at the University of Mainz in Germany recently took the first step towards molecular-sized nanobot, when they created a heat-powered motor using a single vibrating atom trapped in a nano-sized cone of electromagnetic radiation. Amazingly, it has the same working principles as a car engine: expanding, cooling, contracting, then heating. **PB**

Why can't we visualise more than three dimensions?

LEAH SMITH, HEREFORD



Our brains have been shaped by generations of evolution. The fact that we are unable to think in more than three dimensions suggests that visualising four or more dimensions simply provided no survival or reproductive value to our ancestors – this isn't really surprising since our daily lives are played out in a three-dimensional physical space. It is likely for similar reasons that we also find it so difficult to imagine truly infinite space or eternity and other metaphysical concepts. While we can appreciate the meaning of these terms, we struggle to visualise them because our brains have adapted to process the limited space and time that we occupy. **CJ**

Could we manipulate gravity?

SAMUEL CHAABANE, BRIGHTON AND HOVE

Gravity is easy to manipulate: it's just a matter of moving masses around. The challenge lies in achieving anything useful by doing it, as gravity is incredibly feeble. Even so, NASA has succeeded many times, by waiting until planets are in specific locations before launching probes, and using the gravity of the planets to hurl the probes to precise locations. RM

What causes eczema?

DON LEUNG, TWICKENHAM

Although it's common, eczema is not fully understood. It often has a genetic basis and around one-third of children with eczema also have food allergies and many have asthma. Sufferers have an overactive immune system, which responds aggressively to irritants. Eczema can also be caused by an abnormal immune response to bodily proteins. Flare-ups have a wide range of causes, including heat, soap, skin products, and illnesses such as the common cold. A UK team from Newcastle recently came a step closer to an effective treatment, after identifying how a skin barrier protein called filaggrin affects eczema pathways. **ED**

For many people, eczema will disappear or improve in adulthood

IN NUMBERS

8.3bn

The amount of plastic, in tonnes, that humans have created. The majority lies in landfill or the environment.

5×10^{10}

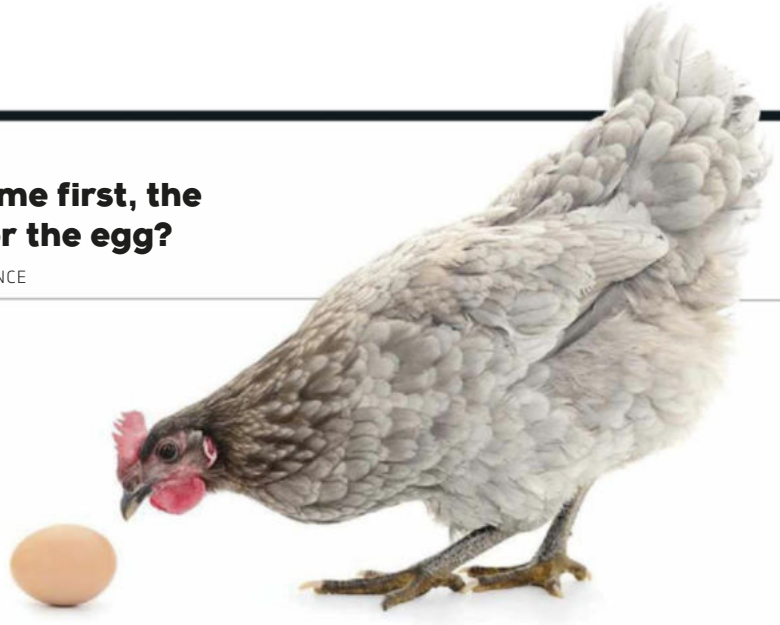
The number of bacteria on 1cm³ of kitchen sponge. Faeces is the only other comparable substance!

6,760

The distance, in kilometres, by which the asteroid 2012 TC4 will pass by Earth on 12 October.

Which came first, the chicken or the egg?

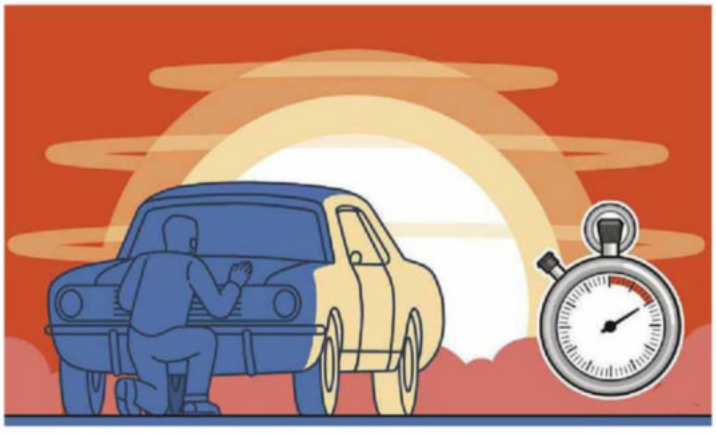
ALAN HEALY, FRANCE



Eggs are much older than chickens. Dinosaurs laid eggs, the fish that first crawled out of the sea laid eggs, and the weird articulated monsters that swam in the warm shallow seas of the Cambrian Period 500 million years ago also laid eggs. They weren't chicken's eggs, but they were still eggs. So the egg definitely came first. Unless you restate the question as 'which came first, the chicken or the chicken's egg?' Then it very much depends on how you define a chicken's egg. Is it an egg laid by a chicken? Or is it an egg that a chicken hatches from? Chickens are the same species as the red jungle fowl of Southeast Asia, although they were probably hybridised with the grey jungle fowl when they were domesticated 10,000 years ago. But it doesn't matter; at some point in evolutionary history when there were no chickens, two birds that were almost-but-not-quite chickens mated and laid an egg that hatched into the first chicken. If you are prepared to call that egg a chicken's egg, then the egg came first. Otherwise, the chicken came first and the first chicken's egg had to wait until the first chicken laid it. **LV**

THE THOUGHT EXPERIMENT

HOW COULD I SURVIVE A NUCLEAR BOMB?



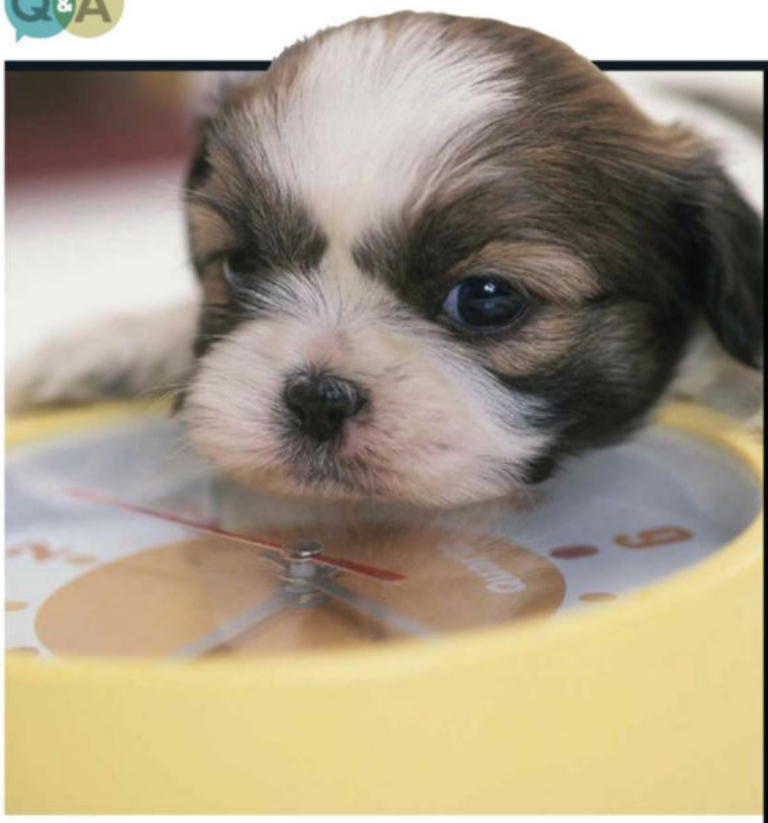
1. THE RADIATION

Nuclear bombs release 35 per cent of their energy as thermal radiation. A 1.2 megaton device, such as the B83 bomb in the US arsenal, will release two million gigajoules of energy. This will cause third-degree burns to exposed skin, at a distance of 10km. If you are already standing next to a wall or a car, duck behind it. Otherwise throw yourself on the floor, feet facing towards the blast, and cover your head with your arms. The thermal pulse will last around 10 seconds for a ground burst explosion. The initial gamma radiation is less dangerous than the heat pulse.

2. THE BLAST

Once that ends, you have a brief lull before the blast wave hits you with 50 per cent of the bomb's energy. It travels at 1,250km/h towards you. At 10km from the impact point, you have 20 seconds to reach safety. The overpressure of 200 kilopascals will feel like being punched all over, simultaneously, which isn't enough to kill you, but it will knock down all buildings and send vehicles flying. The best place to be is the middle of an empty field. Failing that, crouch behind a low wall, away from tall buildings that can fall on you.

PHOTOS: GETTY X2, NASA. ILLUSTRATIONS: RAJA LOCKEY



Do dogs have a concept of time?

FERNANDO GARCIA, SPAIN

Dogs have a sense of time but probably not a 'concept' of time. Human episodic memory means we pinpoint times in the past and look forward to the future. Studies suggest that dogs live very much in the present but, like us, their internal clock or circadian rhythm regulates body processes such as when to go to sleep and get up. Left alone they may become increasingly anxious, indicating that they have an awareness of the passage of time. Plus, they react to a plethora of behavioural cues as though they know that 'it is time for walkies'. But don't be fooled – dogs haven't mastered time management yet! **CC**

Is anything truly random?

HASAN CUTHBERT, CAMBRIDGE

That's a question with practical importance, as randomness is surprisingly useful. Following no laws, random numbers lack any predictability, so when added to text they garble it in a way that no one can unscramble without knowing what numbers were added to encrypt them. Randomness is also useful in simulating the effects of chance on complex systems like stock markets, and for selecting representative samples of patients when testing new drugs.

Researchers typically use random numbers supplied by a computer, but these are generated by mathematical formulas – and so by definition cannot be truly random. In the 1970s, scientists discovered that a widely-used formula produced regularities in its 'random' numbers that undermined countless research studies. True randomness can be generated by exploiting the inherent uncertainty of the subatomic world. In 1957, the UK government unveiled ERNIE (Electronic Random Number Indicator Equipment), which used random quantum noise to choose Premium Bond numbers.

While randomness seems ideal for making totally unbiased choices, there's a problem: the lack of bias only really appears in an infinitely long set of random numbers. In any given collection, there can be astonishing long patterns. So don't be surprised if your smartphone track-shuffling feature randomly plays the same song several times on the trot. RM

Do superfoods really exist?

RACHEL MILLER, ANDOVER

A so-called 'superfood' has no scientific definition and the word is little more than a marketing fad. Fruit and vegetables rich in antioxidants, like blueberries, kiwi fruit and goji berries, often top the superfood list. Antioxidants, such as vitamins A, C and E, are billed as being able to fight havoc-wreaking free radicals, helping to prevent cancer. But evidence for dietary antioxidants' effectiveness is sparse, with some studies suggesting that digestion destroys much of the antioxidant power of berries. Plus, the antioxidant concentrations needed would require you to consume vast quantities of your selected superfoods. However, the foods are all healthy and will enrich a balanced diet. **ED**

PHOTOS: GETTY X2, ALAMY X3 ILLUSTRATIONS: RAJA LOCKEY

HOW IT WORKS

THE HONEYBEE

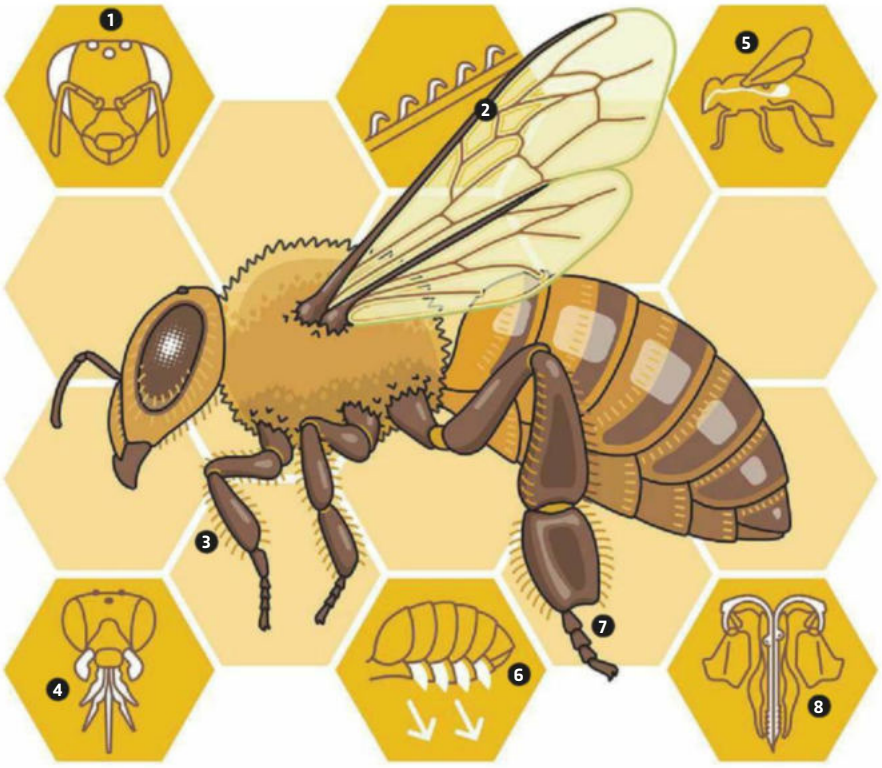
A worker bee spends three weeks as an egg, larva and pupa. When she emerges as an adult, she spends nearly three weeks in the hive, working her way up the ranks as she does different jobs. She'll then spend four days guarding the hive entrance before flying off for the remaining three to four weeks of her life, to gather nectar and pollen. She will fly 800km and make one-twelfth of a teaspoon of honey.

1 Eyes
Two compound eyes, plus three simple 'ocelli' that measure light intensity. Drones have 50 per cent more facets in their compound eyes than workers.

2 Wings
Bees have two pairs of wings but they are connected together by a row of wing hooks that keep them synchronised.

3 Hairs
Pick up tiny electrostatic charges from flowers, which helps them locate good pollen sources and attracts the pollen grains to them.

4 Mouthparts
Grasshoppers can only chew, and moths can only suck, but honeybees can do both since they have mandibles and a proboscis.



5 Honey stomach
The digestive tract has a separate lobe to hold the nectar. Hairs at the entrance filter out pollen grains.

6 Wax plates
Glands between the abdominal segments produce wax that grows outwards as thin plates. Workers mould them to form the honeycomb.

7 Legs
The rear legs have a pollen basket made of hairs, with a central long bristle that skewers the pollen ball in place.

8 Sting
As well as venom, the sting releases alarm pheromone to signal other bees to attack the same target.

Why did the Neanderthals go extinct?

KEVIN SIMPSON, DURHAM

The spread of modern humans across Europe is associated with the demise and ultimate extinction of Neanderthal populations 40,000 years ago, likely due to competition for resources. While the jury is still out on whether or not Neanderthals and modern humans differed in cognition, the ability of a small number of humans to replace a larger population of Neanderthals may have been due to a higher level of culture – our power to develop and pass on knowledge of better tools, better clothing, or better economic organisation. Interbreeding may also have lent us an advantage. Between 1 and 4 per cent of the DNA of all living humans (except sub-Saharan Africans) is Neanderthal in origin. **AP**

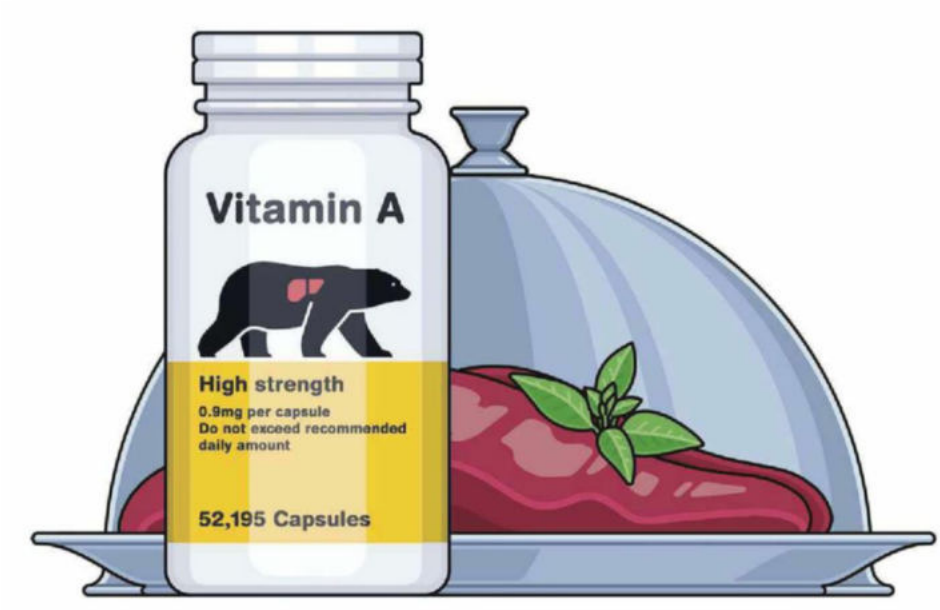
What is the carbon footprint of the internet?

CAROL LENNOX, BROMLEY

Connecting together all the world's smartphones, laptops, desktops and other gadgetry, the infrastructure of the internet uses a lot of energy, and that in turn gives it a hefty carbon footprint. According to a study by the Boston Consulting Group, the internet is responsible for roughly one billion tonnes of greenhouse gases a year, or around 2 per cent of world emissions. **RM**

FACT OR FICTION

YOU WILL DIE IF YOU EAT A POLAR BEAR'S LIVER



FACT

Polar bears are top carnivores that bioaccumulate the vitamin A produced by marine algae lower down the food chain. Because vitamin A isn't water-soluble, it can't be easily flushed from the body and is stored in the liver instead. Bears and seals have generally high levels of vitamin A in their livers but polar bears have the most of any animal. The recommended daily allowance (RDA) for vitamin A in humans is 0.9mg, and you can get that from eating just one-tenth of a gram of the liver from a well-fed polar bear. The entire liver contains enough vitamin A to kill as many as 52 adults! If you spread it out and ate just enough to get your RDA every day, that liver would last you 143 years!

What happens in your brain when you make a memory?

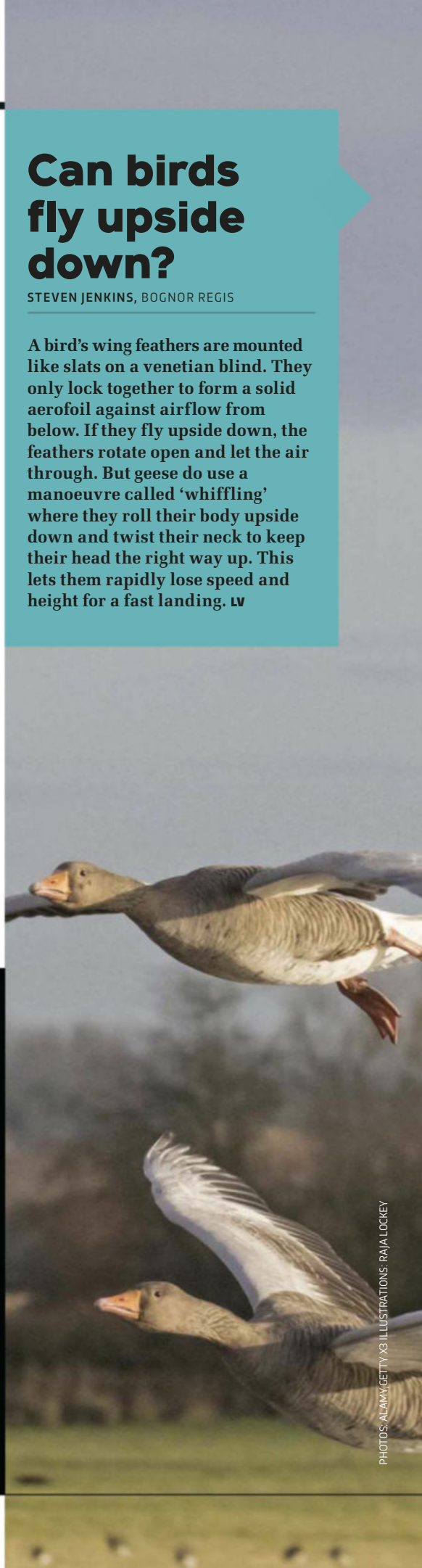
KEITH WALKER, LINCOLN

Memories are formed by the changing strength of connections between networks of brain cells, particularly in the hippocampus, which is found in each temporal lobe (the part of your brain near your ears). A key memory-related process is 'long-term potentiation', which refers to a lasting change in how strongly one neuron influences another. It's tempting to think of memory like a recording, etched permanently into patterns of brain cells, but it's more accurate to see it as a creative process. During recollection, earlier patterns of brain activity are re-enacted – a fragile process that leaves plenty of room for error and editing. **CJ**

Can birds fly upside down?

STEVEN JENKINS, BOGNOR REGIS

A bird's wing feathers are mounted like slats on a venetian blind. They only lock together to form a solid aerofoil against airflow from below. If they fly upside down, the feathers rotate open and let the air through. But geese do use a manoeuvre called 'whiffling' where they roll their body upside down and twist their neck to keep their head the right way up. This lets them rapidly lose speed and height for a fast landing. **LV**



PHOTOS: ALAMY, GETTY X3 ILLUSTRATIONS: RAJA LOCKEY

Love our Q&A pages? Follow our Twitter feed @sciencefocusQA

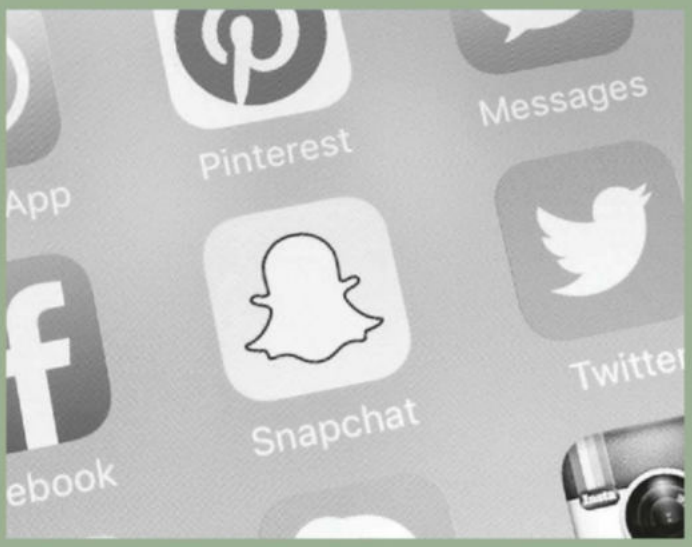
Is hot water better than cold water for handwashing?

PAUL WAYGOOD, SOMERSET

Most of the value of handwashing is the physical rubbing and rinsing action that dislodges bacteria from the skin's surface. A study at Rutgers University in the US found that hot water was no better than cold at removing *E. coli*. In fact, water that is uncomfortably hot actually increases the bacterial load, because it damages the natural protective barrier of your skin. **LV**

Why do apps demand access to our photos and other data?

MARY BELL, SALFORD



Apps on mobile devices live in a 'Sandbox'. This access control technology is built into the operating system, isolating each app from your data, from other apps, and from the hardware of the device, in order to prevent accidental or deliberate damage. When an app needs to process some data, it must ask you for permission first. This is normally for perfectly sensible reasons: a photo-editing app needs access to your photos, or a voice recorder needs access to the microphone. Sometimes an app may want access to more personal information because it is trying to gather data that could then be used for marketing. If you feel your privacy is being invaded, the best thing to do is deny access to your data or simply delete the app. **PB**

HIT OR MYTH?

TAKE PART

Does stainless steel remove garlic smells from hands?

We've teamed up with Prof Mark Lorch, a chemist from the University of Hull, to test whether life hacks really work – and we need your help!

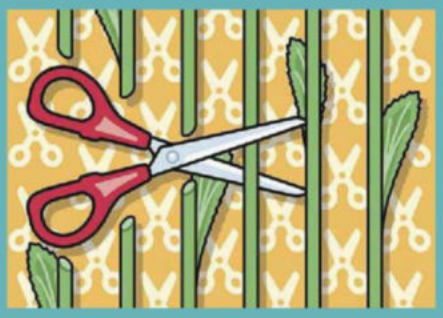
You may have heard that rubbing garlicky hands on something made from stainless steel, such as a spoon, removes the whiff. You can even buy stainless steel soap! But does it work? No one has really tested it under scientific conditions, so my fellow chemists and I (funded by the Royal Society of Chemistry) devised a citizen science experiment to see whether it's a hit or myth.

Hundreds of people took part (you can see how to do the experiment at **bit.ly/hitormyth**) and their results showed that this trick does work! Which leave us with the question of *how* does it work? We are testing some theories in the lab, but this is what we think so far:

Garlic is full of sulphur-containing chemicals, that give it its familiar taste and odour. One of them, called allicin, is probably responsible for making your hands smell. Stainless steel is an alloy, which is predominantly made of iron but also contains chromium. The chromium forms an oxide layer on the surface of the alloy, protecting the iron from rusting. It could be that the oxide layer reacts with the allicin from the garlic, making it cling to the surface of the stainless steel instead of your hands.

We'd love you to take part in our next experiment, which investigates how to stop flowers from wilting. Read on to find out more!

HELP US FIND OUT: DOES A COPPER COIN STOP CUT FLOWERS FROM WILTING?



1. Cut the flowers' stems at a 45° angle. Put them into two identical vases, glasses or jam jars, each filled with 2-3cm of water. Over the course of the experiment, try and keep this water level constant.

2. Find yourself a copper coin (1p and 2p pieces are both made from copper).

3. Clean the coin by giving it a scrub with toothpaste. Rinse the toothpaste off your coin and drop it in one of the vases. Your other vase will be your control.

4. Leave the flowers in a light place where they won't get disturbed.

5. Make a note of which vase of flowers looks fresher over 1, 3, 5, 7 and 10 days, or whether they both look the same.

Tell us your results using the survey on the Hit or Myth blog:

hitormyth.hull.ac.uk

Have you got any life hacks you want us to test? Drop us a line, via *BBC Focus* or on the Hit or Myth blog, with your suggestions.

PHOTO: EYEVINE ILLUSTRATION: RAJA LOCKEY

WHAT IS THIS?

Taters on the terraces
In Weichang County, northern China, terraced fields stretch across the landscape. Terracing is a useful agricultural technique in mountainous regions, as it prevents erosion and water runoff. Potatoes are being grown here, but the method works well for other crops, such as rice, olives, maize and grapes. Farmers around the world have been using terrace agriculture for centuries: the Rice Terraces of the Philippine Cordilleras are a UNESCO site and are believed to be more than 2,000 years old, while inhabitants of the Andes adopted the method for farming maize and potatoes more than 1,000 years ago.

WHAT CONNECTS...

...A HOT BATH AND SLIMMING?

1.

An hour-long soak in the tub might seem like the most sedentary pastime imaginable, but according to researchers at Loughborough University, it's more strenuous than you might think.

2.

A bath at 40°C will raise your core temperature by 1°C. This stimulates your body to release shock proteins to protect against the heat. This metabolic effort uses up blood glucose.

3.

If you spend that hour cycling instead, your core temperature will rise by the same amount. But the bath is actually 10 per cent more effective at lowering peak glucose levels.

4.

Ultimately, cycling burns more calories than bathing, but a hot bath still uses 126 calories per hour, which is as much as a 30-minute walk. Or doing 40 press-ups.

Why are we more likely to get ill if we are cold?

EMRE YORGANCIGIL, TURKEY

It's partly because everyone stays indoors when the weather is bad, which helps germs to spread. But a 2014 study at Yale University found that the rhinovirus that causes most colds can only infect cells that are slightly below body temperature. Warm cells are able to fend off the virus by producing lots of interferon proteins. In cold air, the lining of your nose gets chillier and the cells' immune response is much weaker. **LV**

Could mosquitoes deliver malaria vaccines?

JOHN LESLIE BODEN, NORTHAMPTON

Unfortunately, there is no vaccine against malaria, despite decades of intense research and development. More than 20 potential malaria vaccines are in their trial phases though, which aim to efficiently eliminate certain stages of the life cycle of *Plasmodium* – the malaria-causing parasite that some mosquitoes carry and inadvertently infect us with. There has been a proof-of-concept study that shows mosquitoes could deliver a candidate vaccine through their saliva, but how much they deliver depends on how many times they bite someone, so delivering the right dose of a vaccine would be incredibly challenging. AP

PHOTOS: GETTY X8, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: RAJA LOCKEY

Why do fruits change colour as they ripen?

GARGI PHADKE, INDIA

Unripe fruits are green because of chlorophyll in their cells. As they ripen, the chlorophyll breaks down and is replaced by orange carotenoids and red anthocyanins. These compounds are antioxidants that prevent the fruit from spoiling too quickly in the air. Fruit-eating animals have also evolved to use the colour change as a sign of ripeness and this helps the plant too, since they need animals to eat the fruit to distribute their seeds. **LV**

Do other mammals go through the menopause?

LOUISE SANDERS, SHEFFIELD

Humans, killer whales and pilot whales are the only mammals that experience menopause. We all share a relatively long lifespan that involves mothers living in close quarters with their daughters. It is thought that the older females have therefore evolved to forfeit their ability to reproduce so that they can use their time and energy to nurture their daughters' offspring, as they are more likely to survive than the ageing female's young. This is known as the 'grandmother hypothesis'. Also, grandmothers do not want to compete for vital resources, such as food – another good reason to evolve a menopausal strategy. **CC**

QUESTION OF THE MONTH

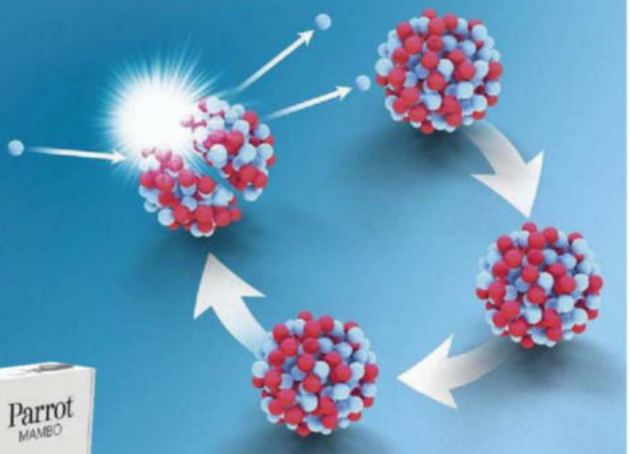
Why isn't thorium used for nuclear power?

DUNCAN WHERRETT, BERWICK-UPON-TWEED

Uranium and plutonium have long been at the heart of nuclear power, but many experts see thorium as a better option. It's more abundant, comes from more politically stable sources like India and Australia, and is harder to weaponise. The reactor design is also simpler, arguably safer, and produces less radioactive waste. Ironically, it's the difficulty of making weapons that explains why thorium designs have yet to become commercially viable. The roots of nuclear power lie in the race to make atomic bombs, prompting many countries to adopt uranium- and plutonium-based designs. With so much investment and expertise already committed to them, they will be around for decades yet. Even so, there is growing interest in thorium designs, especially in China, which may yet make them commercially viable. HS

WINNER!

Duncan Wherrett wins a Parrot Mambo minidrone (£99.99, **parrot.com**). This cool minidrone comes with a mini re cannon take aim at targets and a strong grabber too. It's fast, robust, performs impressive acrobatics and is easy to use. We like.



Thorium absorbs a neutron from fission. Over a month it decays into proctactinium, then uranium. Uranium fissions, releasing energy and neutrons, and the process starts again

NEXT ISSUE:

Could Jupiter become a star?

How do mussels stick to wet rock?

Why is yawning contagious?

Email your questions to **questions@sciencefocus.com** or submit online at **sciencefocus.com/qanda**

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

SEPTEMBER 2017 | EDITED BY JAMES LLOYD

01

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR 2017
ROYAL GREENWICH OBSERVATORY, FREE, FROM 16 SEPTEMBER.

SEE THE LIGHT

The Northern Lights shimmer green and purple over the coal-mining settlement of Svea, in the Svalbard archipelago, in this shortlisted entry to the Insight Astronomy Photographer Of The Year 2017 contest.

Now in their ninth year, the awards received over 3,800 entries from amateur and professional photographers this time around, including the first images of Uranus and asteroids that have ever been submitted to the competition. Other moments captured include a shooting star over the craggy landscape of Portland in Dorset, the International Space Station whizzing past the face of the Moon, and spectacular noctilucent clouds stretching across a moody Swedish sky. The winners are set to be announced on 14 September, with a maximum prize of £10,000. A free exhibition will then open at the Royal Greenwich Observatory's Astronomy Centre a couple days later.

To view more of the shortlisted images, head to bit.ly/IAPY2017

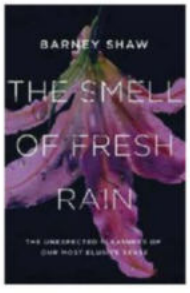
PHOTO: AGURTXANE CONCELLON/INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

02

SMELL THE COFFEE

Freshly-mown grass, wood smoke, seaside air... smells have an uncanny ability to unlock emotions and memories. We discuss the science and psychology of smell with Barney Shaw, author of *The Smell Of Fresh Rain*

THE SMELL OF FRESH RAIN
BY BARNEY SHAW
OUT 7 SEPTEMBER (£14.99, ICON BOOKS).



When we get a whiff of something, what is it we're actually smelling?
It's the light, organic molecules given off by the substance. But it's always a cluster of molecules that you're smelling, not a single molecule. When you smell a cup of coffee, you're breathing in around 800 different molecules, of which about 30 contribute to the odour – it's a kind of 'chord' of smell.

You often find the same molecules reoccurring in unexpected places. There's a molecule in coffee that you also find in the smell of fresh bread, cucumber and old people's skin.

How do these molecules get translated into smell?
The molecules are detected by the millions of receptor nerves inside our noses. There are a number of competing theories for how exactly these receptors recognise the molecules – they might be reading the shape, volume or even the vibrations of the molecules – but the signals get passed on to the brain's olfactory bulb, just behind the eyebrows. Here, the disparate information from our receptor nerves is combined into a single pattern, which the rest of the brain – especially the piriform cortex – translates into a recognisable smell.

Why do smells have such a special power to evoke memories?
The olfactory bulb is bang next door to two important brain structures: the hippocampus, which is crucial for the formation of long-term memories, and the amygdala, which plays an important role in emotions. The close connection between these regions probably explains the unusually evocative nature of smells. In contrast, the other senses take a longer path into the brain, via a structure called the thalamus, which is not part of our brain's emotional centre.

When you ask people for their favourite smells, the same ones crop up time and again – this is often because they're linked to our childhood memories. But it's also cultural. Germans adore the smell of marzipan; Japanese people think it smells of oil or sawdust. If you ask an Ethiopian herder for their favourite smells, they will probably include cow dung, while the most attractive fragrance for Mali's Dogon people is the scent of onions.

There are also unpleasant smells that we come to enjoy because we associate them with delicious food, such as pungent cheese. If babies are given a whiff of Camembert, they'll wrinkle their noses. It's something we learn to appreciate over time.

PHOTO: GETTY

Smells can conjure up memories due to the olfactory bulb's location in the brain

You also talk about the links between smell and mood...
The connection between emotion and smell works both ways. If you smell something disgusting, it tends to make you feel more hostile, and if you're a naturally hostile person, you tend to be more sensitive to disgusting smells. Similarly, research has shown that people who are given something fishy to smell are more likely to be suspicious, while naturally suspicious people are more sensitive to fishy smells.

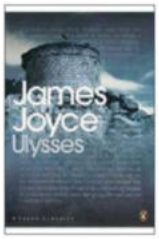
This link probably goes back to our evolutionary past, when a fishy smell might be a warning signal that something was rancid or 'off'.

Has honing your own sense of smell changed how you experience the world in any way?
Being able to recognise a broader range of smells definitely gives the world an extra dimension. I have a son who is blind, and so he's not accessing the world through what is most people's primary sense. He would frequently ask me questions like, "What does three o'clock in the morning smell of?" Writing this book has helped me to put what I smell into words. It's also taught me that someone who relies more on their sense of smell than their sense of sight is getting a more emotional view of their surroundings, as well as one which has more potential to frighten, disgust and delight.

Finally, what's your favourite smell?
Grilled bacon. But my second favourite is perhaps more unusual: the smell of hot tar being laid on a road. It's a rich, thick smell – a blend of chocolate, bad egg and petrol. And it's also got an edge of sulphur, which of course makes it all the more exciting.

AUTHOR'S BOOKSHELF

Three books that inspired Barney Shaw while writing *The Smell Of Fresh Rain*

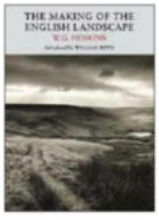


ULYSSES
BY JAMES JOYCE
(£9.99, PENGUIN CLASSICS)

"One of my favourite books: a long, deadpan joke, and brilliant on smells. Joyce can put anything into words, including the smell of Dublin pubs, fried kidneys and babies. He's the only author I'm aware of who has described the very act of sniffing."

THE SECRET OF SCENT
BY LUCA TURIN
(£12.99, FABER & FABER)

"One of the few exciting books I've read on chemistry, by a research chemist working on perfumes. It takes the reader at a gallop through molecules, in search of the explanation of how our noses recognise smells."



THE MAKING OF THE ENGLISH LANDSCAPE
BY WG HOSKINS
(£12, LITTLE TOLLER BOOKS)

"I love non-fiction books which open up unexplored aspects of ordinary life. Until I read Hoskins, I had no idea that our landscape is so full of meaning. I hope my book will open up the sense of smell in a similar way."

03

ASTRONAUTS: DO YOU HAVE WHAT IT TAKES?
BBC TWO, AUGUST/SEPTEMBER
(SEE **RADIOTIMES.COM** FOR DETAILS).

TRAIN FOR SPACE

We live on a planet of over seven billion people, but only around 550 have ever been into space. Astronauts have one of the rarest and most sought-after jobs there is, and they have to earn every second of it.

A new six-part series on BBC Two follows 12 people from around the UK as they take on the astronaut training programme, a gruelling process that's usually reserved for real-life candidates. Overseen by former astronaut and commander of the International Space Station Chris Hadfield, they'll have their fitness, problem-solving skills and psychological mettle pushed to the limit, taking a zero-G flight, getting wet in NASA's underwater lab, and sitting things out inside pitch-black capsules (watch the show to find out why). The winner won't be guaranteed a trip to space, but Hadfield *will* personally back their application when the space agencies next open up for recruitment.

In the meantime, here are some of the lesser-known occupational hazards that any budding spacefarer needs to be wary of…

1. CRUMBS

The food in space is notoriously bad, so you can't blame Gemini 3 pilot John Young for smuggling a corned beef sandwich aboard. Young presented the sandwich to his surprised co-pilot Gus Grissom, who was forced to stuff it in his pocket as it began to disintegrate. The crumbs were the problem: they pose a severe safety risk if they find their way into equipment.

2. FLOATING POO

It's the ultimate floater: NASA transcripts from May 1969 reveal the moment a poo drifted through the Apollo 10 spacecraft. "Give me a napkin, quick!" said Flight Commander Thomas Stafford. "There's a turd floating through the air." A debate promptly ensued over which of the three crew members was to blame. Let's hope they got to the bottom of it…

3. THE COMMON COLD

It seems that no one is safe. In October 1968, after just a couple of days in space, all three Apollo 7 crew members became bunged up with head colds – the low gravity meaning that mucus floated around inside their bodies rather than draining away naturally. Their discomfort led to bad moods, as well as some increasingly terse conversations with Mission Control.

4. COSMIC GORILLAS

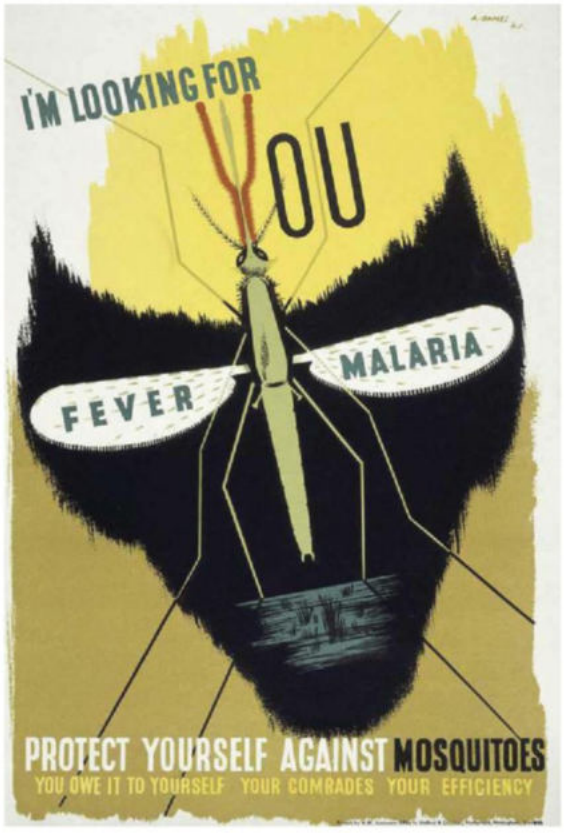
Tim Peake underwent an extensive training programme for his maiden voyage in 2015, but we can bet no one prepared him for marauding gorillas. A camera on the International Space Station captured the moment Tim was chased by a hairy ape, AKA fellow astronaut Scott Kelly, who received the gorilla suit for his birthday.

DON'T MISS

BRITISH SCIENCE FESTIVAL
BRIGHTON, 5-9 SEPTEMBER 2017.
Highlights include an algorithm-generated rave, a debate about clean eating, and a special recording of *Late Night Woman's Hour*.

The Liberian street art shown here depicts the various symptoms of Ebola

This poster was created by British graphic designer Abram Games to raise awareness of malaria during WWII



PHOTOS: BBC, GETTY

04

CAN GRAPHIC DESIGN SAVE YOUR LIFE?
WELLCOME COLLECTION, LONDON,
7 SEPT 2017 – 14 JAN 2018.

CELEBRATE GRAPHIC DESIGN AND HEALTH

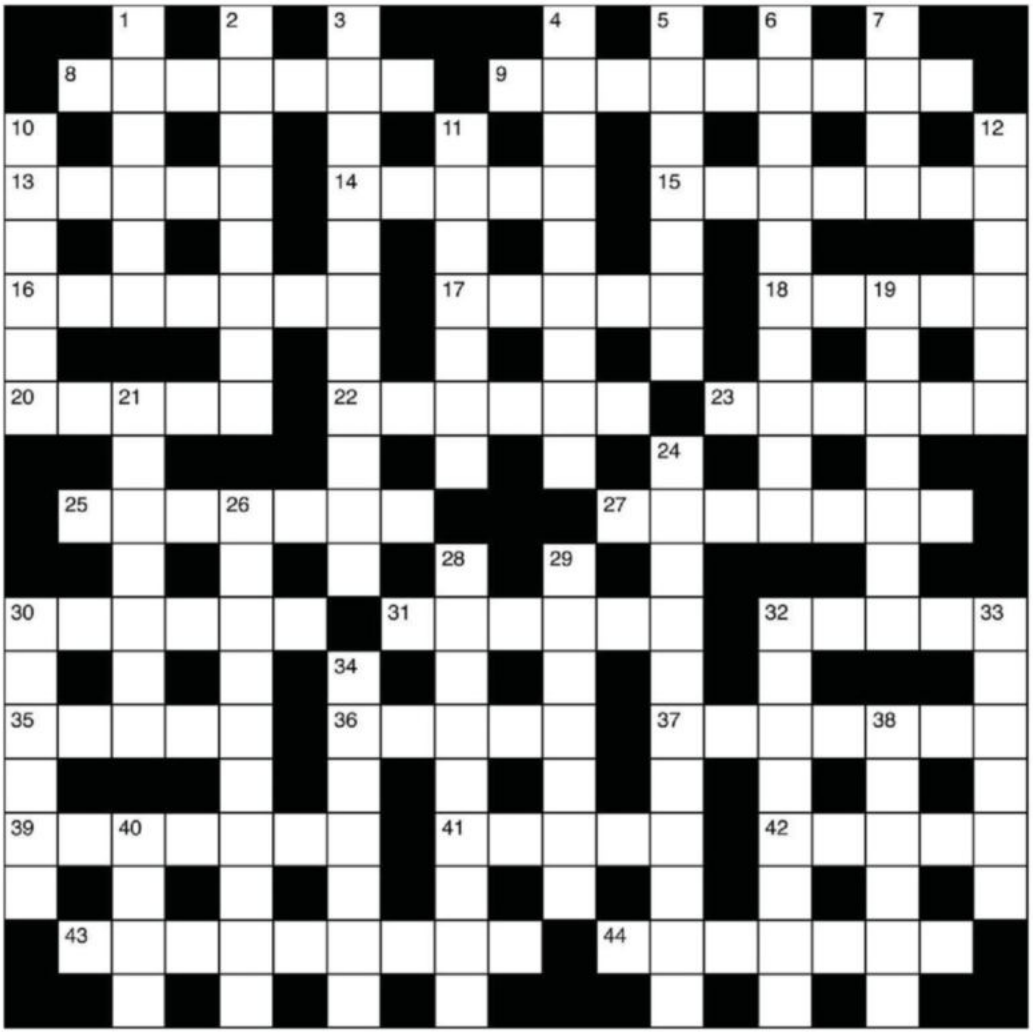
Health and graphic design might not sound like obvious bedfellows, but a new exhibition at the Wellcome Collection reveals that their relationship runs deep.

Around the world, powerful graphic design has been used to raise awareness and inform the public about health and disease, whether that's the recent Ebola crisis, the ongoing fight against malaria, or numerous other epidemics and scares.

Can Graphic Design Save Your Life? features more than 200 objects, from digital teaching aids and 16th-Century anatomical pop-up books to flashing pharmacy signs and comic books advocating safe sex. Together, they show how clever design can offer an immediate, effective way to communicate potentially life-saving messages.

We'll also find out how design can be used on a more subliminal level to alter our behaviour and emotions. Lavish cigarette advertising campaigns from the 1980s will be displayed alongside objects showing the impact of more modern anti-smoking imagery. And the exhibition will also explore how hospital design schemes such as brightly coloured children's wards can help to improve patient wellbeing and make the space feel less intimidating.

BBC FOCUS CROSSWORD
GIVE YOUR BRAIN A WORKOUT



DOWN

1 Earth developed, Saturn initially follows suit (6)
2 A protein involved a poisonous alkaloid (8)
3 Graduation attire for big gun on panel (11)
4 Hid pear in strange excretory organs (9)
5 Blunder involves one registered animal (7)
6 Lie makes one ring about soluble protein (10)
7 German gets free network (4)
10 CIA involvement with detectives is corrosive (6)
11 Hide lubricant in front of waterproof material (7)
12 Quiet trade ruined by old explosive (6)
19 Beer with yours truly, adding last of oregano and pepper
21 Spoken about section of ring road (7)
24 Increases an assembly during artistic period (11)
26 Prince Tony confused by security system (10)
28 British weather greeting clever idea (9)
29 Pick tat out in imitation (7)
30 Nothing to recover as pill is taken (6)
32 Clear ban involved shellfish (8)
33 Request that may be final (6)
34 Preacher finds copy has lots wrong (7)
38 Waste has to leave marine mammal (6)
40 Instructed, say, when tight (4)

ACROSS

8 The lemon somehow has vitamin removed for flavouring (7)
9 Direct lie about amount of liquid (9)
13 Collector's item brings copper to city (5)
14 Temperature at elevated part of the leg (5)
15 Shorten a connection (7)
16 File – rough sleeper has one (7)
17 Move over snow with fellows in boat (5)
18 Father, after short sleep, finds soft leather (5)
20 Large ice cream, outwardly an exact copy (5)
22 Worried, I ring round first to find source (6)
23 Maid runs after silver lizard (6)
25 Nab her ingredients with unknown inductance (7)
27 Shout about ordering men what's left (7)
30 Drinks supplier at school for branch of science (6)
31 A drama about some ships (6)
32 Family may be fluid (5)
35 Companion accepts old mixture (5)
36 Indicate an element of no dimensions (5)
37 Fred's deployed with honour in old social system (7)
39 Fibs about drink – that's an understatement (7)
41 Pagan religion that gets woven, say (5)
42 Old ship, new element (5)
43 Car left in grotto in pressurised vessel (9)
44 Climb adjacent points of a sort of triangle (7)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW** Please be aware the website address is case-sensitive.

Emma Sherlock

"Worms are hugely important, yet seem to be the most under-appreciated animal on the planet"

This month, **Helen Pilcher** talks to **Emma Sherlock**, curator of invertebrates at London's Natural History Museum and champion of the humble earthworm

What do you do?
I study earthworms and look after our fabulous collection of them here at the museum.

How do people react when you tell them that?
There's normally a lot of face pulling. It stops a lot of conversations, or people sometimes ask me when I will work on 'better' animals like frogs or mammals!

Tell us something amazing about earthworms.
They have five hearts or 'pseudo-hearts.' They can regrow certain nerve cells. Some species can jump into the air to avoid predators, while others deliberately detach their tail which then wiggles around while the front half sneaks away. Some are so strong they can pick up and move small stones with their mouths.

So they're not all boring and brown?
Not at all. There are 29 species in the UK, over 500 in the world. They come in all different sizes and colours. Some are striped, some are spotted. Some are iridescent. Others, which often like golf courses or dung heaps, can fluoresce. The biggest, the Giant Gippsland earthworm of Australia, can grow to more than two metres in length.

Impressive. But what have earthworms ever done for us?
They break down decaying plant matter to make the earth rich and fertile. They aerate the soil and convert nutrients into a form that plants can use. They're also an important food source for the many animals that eat them. They're hugely important ecosystem engineers, yet they seem to be the most under-appreciated animals on the planet.

Do they need our help?
One big problem is we have no idea how well or otherwise earthworms are doing because there's no baseline data. If you join the Earthworm Society, you can learn how to become a registered earthworm recorder. We'll train you up, then you can start collecting and sending in your data. This will help us to build up a picture of how our native earthworms are doing.

I've heard there are worm charming competitions. Have you ever taken part in one?
Yes, several times. You have to charm as many earthworms out of the ground as you can by twanging the earth with a pitchfork. I got about 40, so was quite proud of myself, but the winner was a kid and his dad, who got over 100. They were incredible. I have no idea how they did it.

Do you have any unfulfilled earthworm ambitions?
I'm hoping to set up the first Earthworm Conservation Centre, where we'll store earthworm cocoons from around the world. These will be frozen carefully and stored away, so they could be revived later and used to boost flagging populations. There also used to be a worm festival in Australia. Every year, they'd crown someone 'Queen Earthworm'. That's a title I'd really like.

What do you do when you're not working with earthworms?
I enjoy playing tennis. My old club had grass courts. When I finished a game I'd sometimes go to the bar, then as I walked past the courts on the way home I'd stop to see if any earthworms had come to the surface. Tennis courts are a great place for earthworm watching.

Emma Sherlock is curator of invertebrates at London's Natural History Museum.

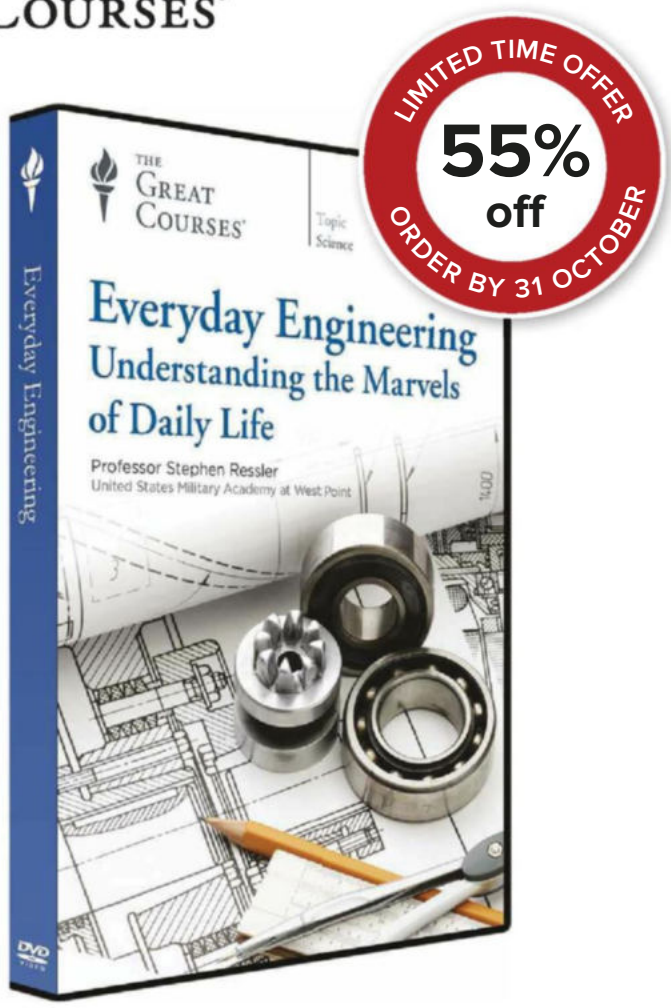
DISCOVER MORE

To listen to an episodes of *The Life Scientific* with top scientists, visit **bit.ly/life_scientific**

NEXT ISSUE: DR ELEANOR SCHOFIELD

ILLUSTRATION: DAVID DESPAU

THE GREAT COURSES®



Understand the Genius of Everyday Technologies

Great masterpieces of engineering are everywhere. The achievements of everyday engineering are worth admiring for their own sake. They represent some of the most inspired thinking of our civilisation, and by looking under the hood to see how these technologies work, you learn about basic scientific principles that have remarkable applications.

Everyday Engineering: Understanding the Marvels of Daily Life is an indispensable guide to the way things work in the world. Conducting this eye-opening tour is Professor Stephen Ressler, an award-winning civil engineer and a nationally honoured leader in engineering education. No background in science or engineering is needed to follow this riveting presentation, which gives you deep insight into the complex systems that enhance your life—providing a broad understanding of everyday engineering that you can apply to any technological issue that crosses your path.

Offer expires 31/10/17

THEGREATCOURSES.CO.UK/6FS

0800 298 9796

Everyday Engineering: Understanding the Marvels of Daily Life

Taught by Professor Stephen Ressler
UNITED STATES MILITARY ACADEMY AT WEST POINT

LECTURE TITLES

1. Engineering and Technology in Your World
2. Your House as an Engineered System
3. Three Structural Systems for Load Bearing
4. Platform-Framed Housing Construction
5. The Building Envelope
6. Site Design and Storm Runoff
7. Dam, Reservoir, and Aqueduct Design
8. Water Treatment and Distribution
9. Wastewater Disposal and Treatment
10. Fossil Fuels: Coal, Oil, and Natural Gas
11. Power Generation from Coal
12. Oil, Gas, and Nuclear Power
13. Renewable Sources of Electricity
14. Electrical Power Transmission: The Grid
15. Electrical Power Distribution
16. Everyday Thermodynamics: Refrigeration
17. Heating, Ventilating, and Air-Conditioning
18. Home Energy Efficiency
19. Passive Solar and Net-Zero-Energy Homes
20. The Plain Old Telephone Service
21. The Global Telecommunications Network
22. Cellular Phone Technology
23. Satellites and Satellite Communications
24. Simple Machines around the House
25. User-Centred Design
26. The Internal Combustion Engine
27. Torque, Power, and Transmission
28. The Drivetrain
29. Suspension, Steering, and Braking
30. Highway Engineering
31. Traffic Engineering
32. Everyday Bridges
33. Tunnel Engineering
34. The Railroad
35. Solid Waste Disposal and Recycling
36. The Future: Engineering for Sustainability

Everyday Engineering:
Understanding the Marvels of Daily Life
Course no. 1116 | 36 lectures (30 minutes/lecture)

SAVE UP TO £45

DVD	~~£79.99~~	**NOW £34.99**
Video Download	~~£54.99~~	**NOW £34.99**

+£2.99 Postage and Packing (DVD only)

Priority Code: 149385

For over 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available any time, anywhere. Download or stream to your laptop or PC, or use our free apps for iPad, iPhone, Android, or Kindle Fire. Over 600 courses available at www.TheGreatCourses.co.uk.

SAVE MONEY ON YOUR BROADBAND AND TV BILLS WITH THE CARPHONE WAREHOUSE SWITCHING SERVICE

SAVE UP TO £322* A YEAR

Call: 0800 090 1669

Save money and still get the service you want, with a little help from us

SWITCH IN THREE SIMPLE STEPS

1. call our freephone number:
   0800 090 1669
   Our lines are open:
   Monday - Sunday, 8am-9pm
2. Tell us how you use the internet and TV at home
3. We'll help you switch to the perfect deal so you can just sit back and relax

How much are you spending every month on your internet and TV service? If you've been with the same provider for 12 months or more, it's likely you could save up to £322* a year by switching to a service which is tailored to your needs.

Pick up the phone and speak to one of our friendly UK advisors. They'll listen to your requirements and then recommend the right service for you, using our Ofcom-approved calculator to compare over 11,000 deals on your behalf.

If you are happy with the package we find you, we can organise everything in a few minutes while you're on the phone with us. Most people have their new service installed within 3 weeks of calling. It really is that simple.

We compare the major UK internet, TV and Phone suppliers, including:

TalkTalk For Everyone · Virgin media · sky

*SimplifyDigital customers save on average £322 a year. Data based on 4,342 SimplifyDigital records between July – September 2016.